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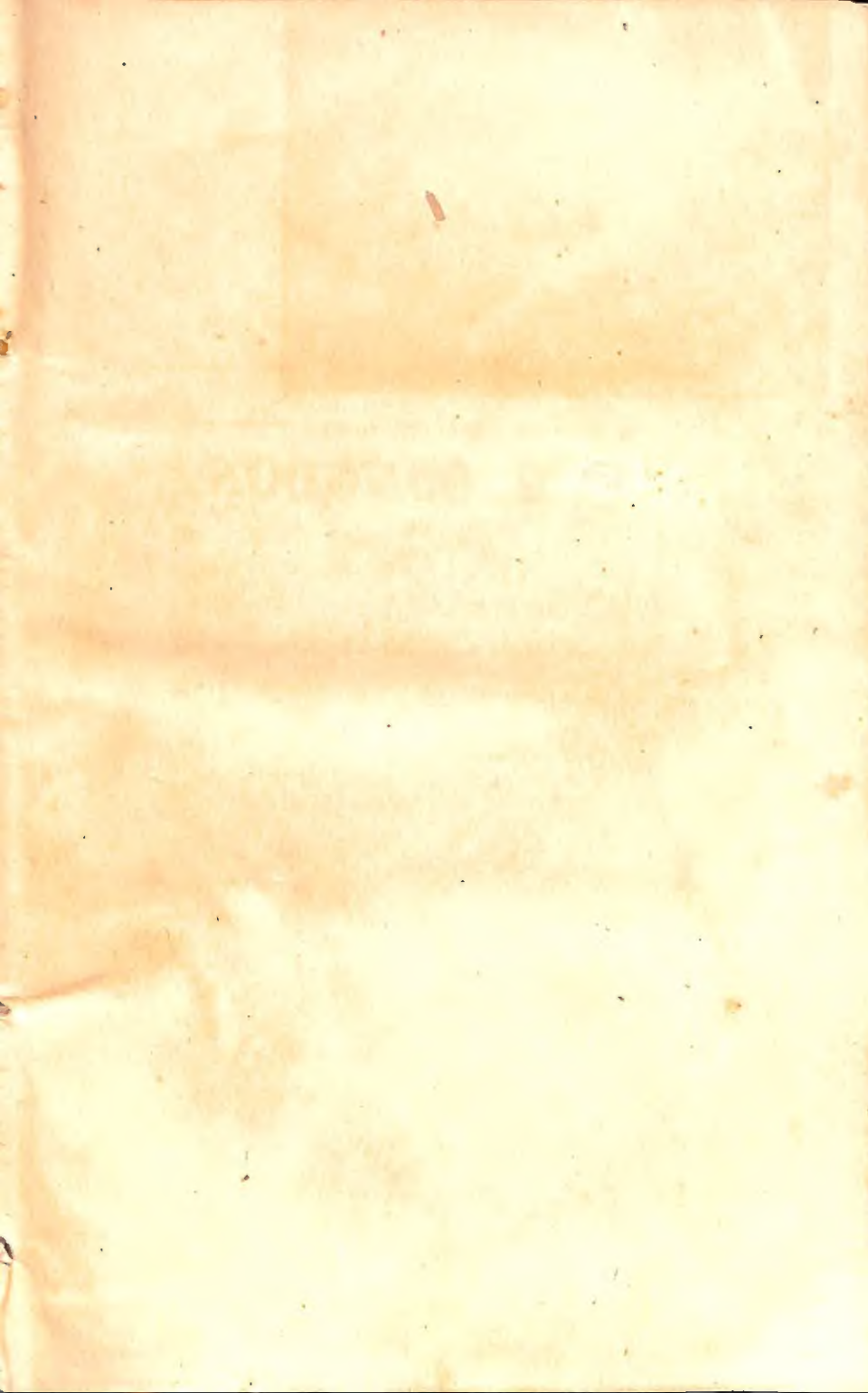
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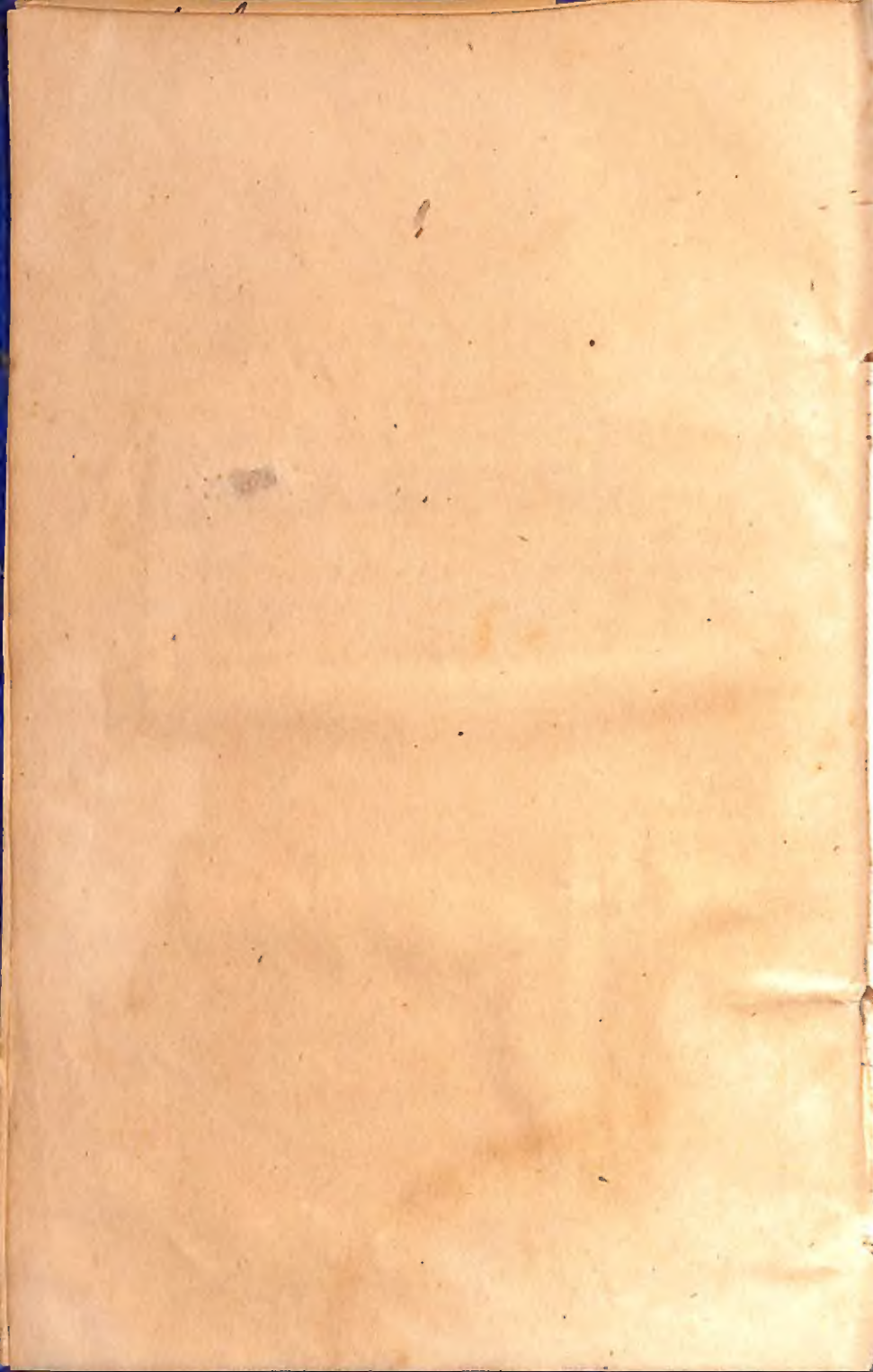
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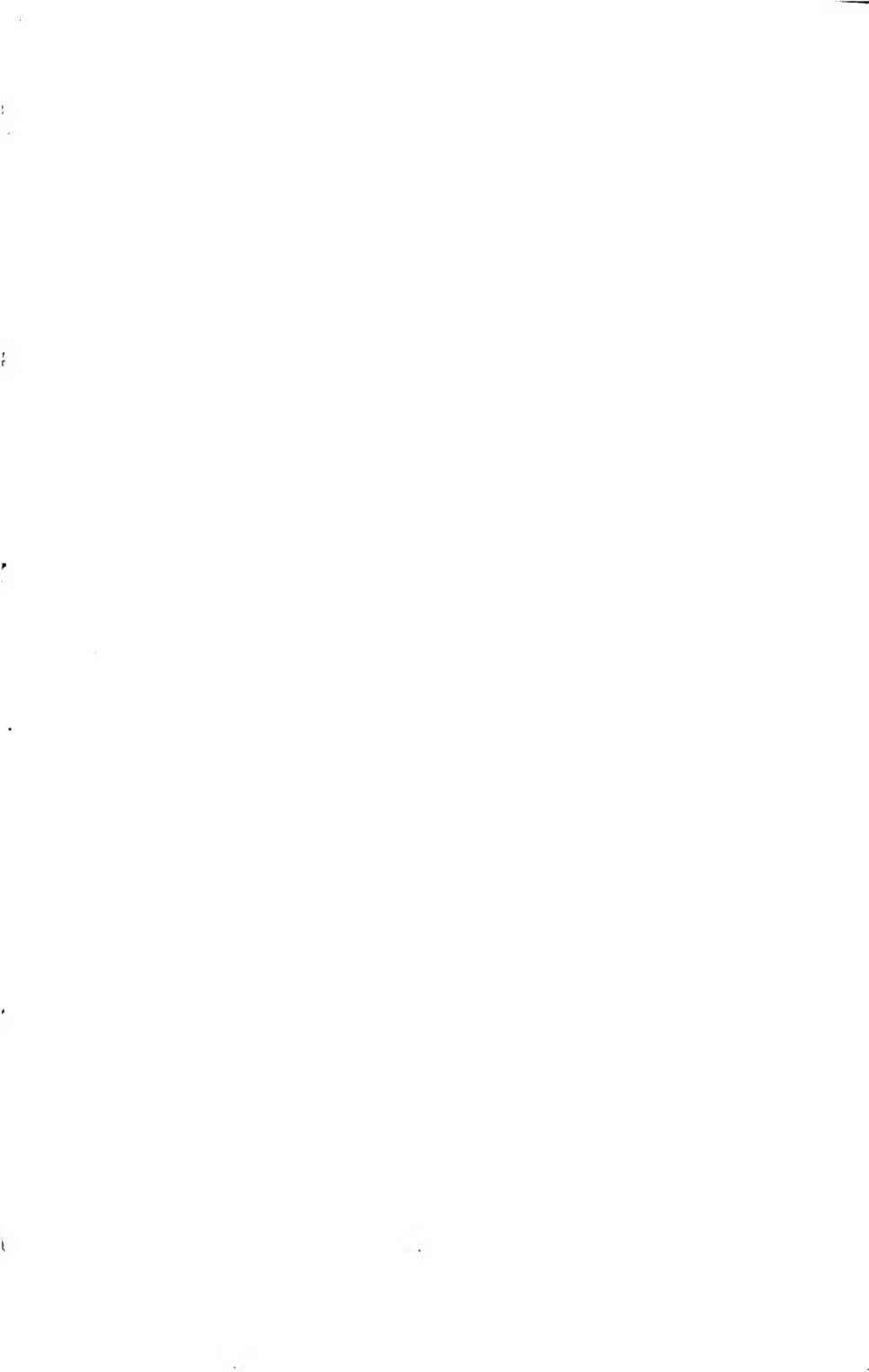
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N. B. CONGDON.

No. 62









LECTURES
ON THE
SCIENTIFIC EVIDENCES
OF
NATURAL AND REVEALED RELIGION.

BY
WILLIAM C. LARRABEE, A. M.,
PROFESSOR OF MATHEMATICS IN INDIANA ASBURY UNIVERSITY.

EDITED BY
REV. B. F. TEFFT, D. D.

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LECTURES ON THE SCIENTIFIC EVIDENCES
OF
NATURAL AND REVEALED RELIGION.

LECTURE I.

THE NATURE AND PROPERTIES OF MATTER.

Design of these lectures—Matter—Properties of matter—Extension—Divisibility—Resistance—Passiveness—Attraction—Cohesive attraction—Capillary attraction—Chemical attraction—Gravitation—States of matter—Gas—Indestructibility of matter—Elementary substances.

1. *Design of these lectures.*—My design in this course of lectures is to help you become wise and good—to improve your intellect and your heart—to add to your knowledge, your faith, and your charity. To accomplish this object, I shall describe to you such of the works, and explain such of the laws of nature, as may suit my purpose, in a manner as clear and simple as possible, avoiding, whenever it can be done, the use of hard words and technical terms; and when I must use them, I will endeavor to define them, so as to remove all obscurity and doubt from your mind. I shall endeavor to show, so far as human sagacity may discover it, the design of Providence in such of his works as we may describe, exhibit the benevolence of that design, and illustrate the wisdom by which it is accomplished.

I trust that when you arise from the perusal of these lectures, your faith in the existence of God—the creator, preserver, and ruler of all things—will be confirmed, your

idea of his power enlarged, your admiration of his wisdom increased, and your gratitude and love to him, for his goodness rendered, more deep and ardent.

2. *Matter*.—All those beings in the universe of God, which may be perceived by all or any one of our senses, are composed of what is called matter. This word is derived from the Latin word *materia*, and means the stuff out of which all other things are made. When we speak of any definite portion of matter used in the construction of any thing, we call it substance; and when we speak of matter assuming a form or shape, we call it body. Thus, a watch is a body; gold, silver, glass, and steel, are its substances. The gold, the silver, the glass, the steel, the brass, and whatever else helps form the watch, are matter.

For a long time philosophers uselessly disputed about the origin of matter. Most of the ancients believed that it existed from all eternity, governed by its own laws, independent of God himself. But modern wise men all agree that in the beginning matter was created by God; that it received from him those wise and wonderful laws, by which it is uniformly governed; and that by his hand it was molded, in accordance with these laws, into the various shapes and forms we so much admire.

3. *Properties of matter*.—It was in the power of the Creator to give matter such laws and properties as he pleased. There was no necessity why it should have any one property, which it has, more than any other, which it has not. The divine Being gave it such properties, and imposed on it such laws, as in his infinite wisdom seemed best. Man, whose mind is not sufficiently comprehensive to grasp in advance the purposes of the Almighty, could not determine, without observation and experiment, any of the properties of matter. But means of observation lie all along his pathway through life, and means of experiment are by

no means difficult of use; so that any one may easily study the laws of nature,

“And look through nature up to nature’s God.”

Only the most obvious properties need be noticed in this lecture.

4. *Extension*.—The merest child must have observed what is called the extension of matter. It is one of the earliest ideas of infancy. We have the idea long before we know the name. All our ideas of magnitude and distance are founded on extension. Extension may be measured in three ways, called the three dimensions of extension. These are length, breadth, and thickness. All bodies are supposed to have all the dimensions, though some have dimensions in some or even all directions, hardly appreciable. There is, indeed, no limit to the variety in the size of bodies, though none can be so small as to have absolutely no extension.

5. *Divisibility*.—From the changes which bodies may undergo in their extension, arises another property of matter, called divisibility. A mass of matter of any given dimensions may be broken up and diffused over any desirable extent. A rock may be ground to fine sand. A piece of gold may be hammered out to an inconceivable degree. A grain of salt, or a drop of coloring liquid, may be diffused through a gallon of water. It is sometimes said, in books of natural philosophy, that matter is infinitely divisible. This only means, that inasmuch as a particle of matter can never be made so small as to have no extension, that particle must be susceptible of division into two or more particles, provided you have the right kind of instruments to continue the division. No one, however, has ever yet invented the instruments to divide matter infinitely, and it is doubted whether even any Yankee ever will do it. It is also the opinion of philosophers, that matter is composed of ultimate atoms, which cannot be divided. If this be so, there must be an end to the divisibility of matter

6. *Resistance*.—What we call resistance is sometimes called impenetrability, and sometimes solidity; but resistance better specifies the property. Resistance is experienced when you place your foot on the ground, or bump your head against a post, or thrust your hand into the water, or wave it in the air. Resistance is reciprocal between the conflicting bodies, and seems proportioned in degree to the hardness of the bodies. Resistance must not be confounded with elasticity, a property of some bodies, producing reaction when struck. Gum-elastic is remarkable for its elasticity, but not for its degree of resistance.

7. *Passiveness*.—Matter has no power to act of itself. It can neither move itself when at rest, nor stop itself when in motion. It patiently suffers itself to be acted on by whatever force may be present. A stone lying on the surface of the earth would lie there for ever, unless it were moved by some power; and when once put in motion, it would continue until arrested by some resisting influence. A ball rolling on the earth is soon arrested by the roughness of the ground. On the ice it would move much longer, and in the air longer still. Yet there is resistance even in the air, which must gradually operate to bring any body moving in it to rest. The planets, which move for ever, are beyond the influence of our atmosphere, and the space, in which they move, is not known to be occupied by any resisting substance. Even the matter of your body has no power to move itself. Were it not for the mind, which has power such as no matter has, you could no more move about than a stone can.

8. *Attraction*.—There is another very interesting property of matter, called attraction. This word implies the existence at least of two things, of which one is drawn toward the other, or both mutually drawn each toward the other. As applied to matter, it means that two or more bodies, or

two or more particles, are mutually drawn toward each other.

Attraction takes different names, according to the circumstances under which it is exerted. Two smooth bodies of the same kind, as two pieces of lead, will, when pressed together, adhere. Particles of soft clay, or of bread, will, when pressed into contact, adhere in a mass. This species of attraction is called cohesive attraction. It is this which makes dew collect in drops on the grass, and rain fall in drops. Cohesive attraction gathers the mist forming the rain and the dew into round drops. It is owing to this species of attraction that bodies retain their determinate form. When by any means this power is overcome, the body crumbles to pieces. Thus, some kinds of rock put in the fire lose their cohesion, and drop all to pieces.

9. *Capillary attraction*.—The Latin name for what we call a hair, is *capilla*. A hair is hollow like a straw, and, therefore, any very small tube is called a capillary tube, or simply a capillary. Now, when a small tube, like a straw, is placed in water or any other liquid, the water will rise higher inside than outside the tube. This is supposed to be owing to attraction between the water and the matter of the tube. When, therefore, attraction occurs under these circumstances, it is called capillary attraction. It is on this principle that water will rise up in a sponge, or piece of cloth, or lump of sugar. This species of attraction is nearly allied to cohesive.

10. *Chemical attraction or affinity*.—It often happens that two bodies of different kinds unite together, and form a third materially differing from either. The species of attraction by which the union is formed is called chemical attraction, or attraction of combination, or, more frequently, affinity. Thus, oil and lye will unite by affinity and form soap. Examples of this kind of attraction are numerous, both in nature and in art. We shall hereafter more fully

explain the conditions, laws, and effects of this species of attraction, and draw therefrom many illustrations of our subject.

11. *Attraction of gravitation.*—The attraction existing between all bodies on the surface of the earth and the earth itself, and also between the earth and moon, and all the planets and the sun, is called gravitation. It is this attraction between the earth and bodies on its surface, or near it, which gives all terrestrial objects their weight. The weight of a body is nothing more than the measure of the power or force by which it is drawn toward the earth; and this force is in proportion to the quantity of matter which the body contains. A barrel of flour is drawn toward the earth by a force which we call two hundred pounds, and a ton of hay by two thousand pounds. It is owing to gravitation, that bodies on the surface of the earth do not tumble off as the earth revolves on its axis, and that the earth and planets maintain their places in their annual revolution.

The theory of gravitation is a splendid, a magnificent theory, by which we explain the complicated movements of the planets, and suns, and stars. We shall refer to it again hereafter.

12. *States or conditions of matter.*—Matter is found in three states—solid, liquid, and aerial. Some substances often change their state. Thus, water, which is a good specimen of matter in a liquid state, may become solid, as in ice, or aerial, as in steam or vapor. Iron and lead, though naturally solid, may easily be rendered liquid. Mercury, or quicksilver, is usually liquid, but becomes solid by cold. Every substance may be said to have a natural state or condition, which it maintains under ordinary circumstances, and out of which it is forced only by extraordinary influences. Thus, the natural state of water is obviously liquid, and it assumes other forms only by deficiency or excess of heat. Whenever a body is forced out of its natural condi-

tion by any cause, it returns to its former state as soon as the cause is removed. Steam returns to water on the removal of excessive heat.

13. *Gas*.—There are certain substances whose natural state seems to be aerial; but they may and often do become combined in solid forms. Under favorable circumstances these substances are set free, and resume their aerial form. To substances of this kind the early German chemists gave the name gas, or, as originally written, ghoast. This word literally means spirit, as our word ghost now does. They supposed that the aerial substance was imprisoned in the solid, as the soul or spirit is in the body, and being set free, became at once what it originally had been—spirit, or ghost, or gas. The aerial substance existing in coal being set free, becomes the well-known carbonic acid gas. Two aerial substances combined in the form of water, become, when the water is decomposed, oxygen gas and hydrogen gas. Two of these gases, oxygen and nitrogen, with a sprinkling of carbonic, form, by mixture or combination, without changing their natural state, the air which we breathe. In appearance and mechanical properties the gases do not differ materially from common air.

14. *Matter indestructible*.—We have seen that matter may change its condition and form. But it cannot be annihilated. Place a piece of ice in a vessel over the fire, and it will become water. Continue the heat, and the water will become steam. Subject the steam to certain conditions, and it will be resolved into the original elements of water—oxygen and hydrogen gas. Yet the matter is all there; nothing is lost. It has only changed its form. So a piece of wood placed in the fire loses its form; but the matter of which the wood was composed is not destroyed. Its form has been changed from wood to ashes, and smoke, and gas. If you only had the means of collecting the products of combustion, you would find, on experiment, that they would

weigh as much as the wood did. Man may change at pleasure the form of matter. But he cannot destroy the substance. The Almighty alone, who created matter, can annihilate.

15. *Elementary substances.*—Bodies are called simple or compound, according as they consist of one or more of what is called elements or elementary principles, or, more frequently, elementary substances. Our word element is the same as the Latin word *elementum*, and means the first rudiments, principles, or constituent parts of things. Thus, the letters of the alphabet are the elements of words, and the nine digits are the elements of numbers.

When the chemist has presented to him any body, he takes it into his laboratory, or chemical workshop, and experiments upon it, to see if he can resolve or separate it into two or more substances. This process he calls analysis. Thus, if he experiments on water, he can resolve it into two gases, oxygen and hydrogen. Water is, therefore, a compound body, and its elements are oxygen and hydrogen. If he applies his analysis to the oxygen and hydrogen, he finds he cannot separate either of them into any more simple parts. He therefore concludes that oxygen and hydrogen are elementary substances. The ancients supposed there were in nature but four elements—fire, air, earth, and water—and that out of these all things were made. But modern investigations have determined upward of fifty.

Of these we shall describe in this lecture only the most important, being about twenty.

(1.) Oxygen.—This is, perhaps, the most important of the elementary bodies. It exists naturally in a gaseous state, constituting one-fifth of the air we breathe. Its existence in the air is indispensable to the production and continuance of animal and vegetable life. It is wonderfully prone to enter into combination with almost every thing on the earth. Uniting with the juices of vegetables, as cider and grape

juice, it turns them sour; and hence it is called oxygen, from two Greek words, which signify, *to produce an acid*. You well know that cider exposed to the air becomes vinegar. This is because it attracts the oxygen from the air, and turns sour, or acid. Oxygen exists in a solid state in combination with almost every mineral or earthy substance on the globe. It also forms a constituent elementary principle in all trees and vegetables, and in the bodies of all animals.

(2.) Chlorine.—This substance, though a gas in its elementary state, never is found naturally in this form. It is found in great abundance in combination with solid bodies. It is the chief constituent of common salt. It is called chlorine, from a Greek word meaning *green*, because its color is of a greenish tinge.

(3.) Hydrogen.—This is a gas in its elementary state. It never exists, however, naturally in a separate form, but is found always in combination. United with oxygen it forms water; and hence it is called hydrogen, from two Greek words, signifying, *to produce water*.

(4.) Carbon.—This word is from the Latin word *carbo*, which means a *coal*. A pure, burning coal, taken from the fire, and suffered to cool, will give you a good specimen of carbon. It is the chief ingredient of all vegetables, and enters largely into the composition of animal bodies. It is the principal substance forming all coals dug from the earth. Combined with oxygen, forming what is called carbonic acid, it enters into the composition of chalk and limestone. It also forms the diamond, the hardest and most brilliant substance in nature. This appears strange. No one would suspect a diamond and a piece of charcoal to be one and the same substance. But so it is. The only difference between them is, that in the diamond the particles of carbon are arranged in a peculiar manner, by a process called crystalization. Many mineral substances are capa-

ble of being crystalized, not only by nature, but by art; yet the crystalization of carbon, so beautiful in nature, proves inimitable by man.

(5.) Nitrogen.—This exists naturally as a gas, forming about four-fifths of common air. From its entering largely into the composition of nitre, known to you, perhaps, under the name of saltpetre, it is called nitrogen, meaning, *to produce nitre*. It does not exist in vegetables, but does in animals, forming their characteristic element, whereby they are distinguished from vegetables.

(6.) Silex.—This word is from the Latin, and means a *flint*. It is one of the most abundant principles in nature. It forms the groundwork, the solid foundation, of the matter of our globe. It exists in small quantities in vegetables and in animals.

(7.) Potash.—This substance is well known. Lye formed from ashes consists of potash dissolved in water. Potash exists largely in all vegetables, and is found in animals.

(8.) Soda.—This is nearly allied to potash in many of its properties, and exists in all animals. It is the foundation, the base, of common salt.

(9.) Lime.—This is a very abundant principle in nature, existing in minerals, animals, and plants. In minerals it forms limestone, marble, and chalk. In animals it forms bones and shells. In vegetables it exists in various forms.

(10.) Alumina.—This is abundant in nature, forming the chief ingredient of every species of clay. Bricks, porcelain, and earthen ware, of every kind, owe their value to alumina. Many rocks, especially those called slate, consist mostly of this substance. It is also an ingredient of the well-known substance called alum. It does not, however, exist at all in vegetables or animals. It is not, therefore, true that man is made of clay. It should be observed, that the five last-described substances—sillex, potash, soda, lime, and alumina—are not considered, according to modern science, strictly

elements. They have each been decomposed. Thus, potash is found to consist of oxygen and a metallic base called potassium; soda, of oxygen and sodium; lime, of oxygen and calcium; alumina, of oxygen and aluminum; and silex, of oxygen and silicon. But, inasmuch as silicon, and potassium, and sodium, and calcium, and aluminum, never exist in a separate state, but are generally presented to us in the form of silex, and potash, and soda, and lime, and alumina, and as these latter substances are well known, it better suits the purposes of these lectures to call them elements.

(11.) Phosphorus.—This substance is named from a Greek word meaning *to bring light*. It is the same as the Latin word *lucifer*. Its appearance in its elementary state is much like wax, and it takes fire immediately on being exposed to the air, and gives a peculiar light. This circumstance gives it its name. Its importance arises from its forming, with lime, the solid parts of the bones of animals.

(12.) Sulphur.—This substance is well known. It exists naturally in its elementary state, and is an abundant constituent of the mineral kingdom. It is found also in all animals, and in many vegetables.

(13.) Metals.—More than one-half of the elementary substances now known are metals. Of these only a few need be mentioned in these lectures. Iron is very abundant and very useful. It enters into the composition of animal bodies. Zinc is used both alone and in combination with copper, forming brass. I know not as it enters into animal organization, though we do sometimes speak of one's having a brazen face. Lead is very abundant and very useful, yet very poisonous. Tin is much used in manufacturing ware. Copper is useful, not very abundant, and, like lead, poisonous. Mercury, sometimes called quicksilver, naturally exists in a fluid state, but becomes solid by cold. It is of great importance to man, both as a material of art and a

medicine for disease. Silver and gold, with their uses, are too familiar to require notice.

These are all the elementary substances we may have occasion to mention in the course of these lectures. It is wonderful how great a variety of beings these few elements may form. The variety is owing to the different manner, and different proportions, in which they combine. Their combinations are effected by fixed laws, under the direction of the great Being who made the universe. These laws exhibit wonderful wisdom, and in their design may be seen evidences of wonderful goodness. We have not stopped in this lecture to explain these laws, nor inquire into their design, nor exhibit the benevolence of the contrivance, and the skill of execution. But we shall do all that hereafter

LECTURE II.

THE PROPERTIES AND CLASSIFICATION OF ORGANIC BODIES.

Organic bodies—Design thereof—Stability of form—Renewal—Complicated nature—Combine the solid and the fluid—Mode of origin—Of growth—Death—Classification of organic bodies—Resemblance between plants and animals—In the mode of origin—In the functions of their organs—Distinction between plants and animals—The stomach—Classification of animals—Invertebral animals—Vertebral animals.

16. *Organic bodies.*—We have seen (§15) that material bodies are, as to their elements, either simple or compound, and, as to their condition, (§12,) either solid, liquid, or gaseous. We now proceed to another classification, still more important and interesting. It is founded on what is called organization. Innumerable varieties of bodies in nature are endowed with what we call life. To maintain life, certain instruments or organs are necessary, producing a peculiar structure called organization. This structure is very curious and wonderful, varying greatly in the different varieties of animated beings, yet always contributing to the same great design—the preservation of life.

17. *They exhibit peculiar design.*—The closing remark of our last article deserves amplification. Beautiful as are many of the mineral forms in nature, yet no design is evident in the particular form which any inorganic substance may assume. All mineral substances, when left to act freely, assume forms regular and well defined. Some take the form of the pyramid, some of the cube, some of the prism; and, indeed, almost every possible geometrical solid is assumed by one or another of the mineral substances found in the earth. The general law of nature demands a regular and well-defined form in all inorganic bodies. If there be found, as there often is, a mineral substance not regular in form, there may usually be discovered some mechanical cause for

the exception. Circumstances did not allow the substance to act freely, so as to assume the type of its nature; but yet no design in these forms is apparent. The substance might just as well exist in one form as in another—in a shapeless mass as in a well-defined crystal. If there be design in their inimitable forms, it can have no relation to the preservation of the individual being, or the species to which it belongs. It is far otherwise in organic bodies. Every organ has its specific design. All contribute to the existence of the being, or the reproduction of its like. In a plant the root, the stem, the bark, the leaves, the flower, and the fruit, have each their specific design. In the body of man, and of all animals, every part has its use. To provide against accidents, some parts are duplicate; but none can be destroyed without inconvenience; and in many of the organs injury produces inevitable death.

18. *Stability of their form.*—As all the parts of organic bodies are designed to accomplish a specific purpose, it would seem necessary that the form produced by the arrangement of the several parts should be stable. From its earliest existence each organic body exhibits a tendency to the distinct form of the species to which it belongs. As it advances to maturity, each part becomes developed, until the whole structure arrives at perfection. Whatever internal or external changes come over it, the form still remains the same. Change the form, and the organs no longer answer their purpose, and the being dies. Yet inorganic bodies may change their form to any extent, and still retain all their characteristic properties. The same body may, as has been seen, (§12,) be, in succession, a solid, a fluid, and a gas. The form is by no means essential.

19. *Subject to renewal.*—Though organic bodies cannot change their form and live, yet the substance of which they are composed is constantly changing. These changes are most remarkable in the higher orders of animals, which

possess an extensive system of circulating and absorbing vessels. Even in the bones scarcely any portion of the substance which originally composed them is permanently retained in their structure. So rapid are the changes, that doubts may be reasonably entertained, whether any portion of the body continues the same for any considerable time. The ancients supposed about seven years required for the complete renovation of the human body. But modern observation tends to prove that a much shorter period may effect a complete change in the substance of every portion of the living fabric. Inorganic bodies suffer no change of the kind. Their substance remains the same for indefinite ages; and when any loss is sustained, they have no power of renewal.

20. *Complicated nature of organic bodies.*—We have seen that there are over fifty elementary substances. But very few of these are ever found in organic bodies. Oxygen, hydrogen, nitrogen, and carbon, with a little sulphur and phosphorus, and some few alkaline, earthy, and metallic bases, form the whole catalogue of elements of organic bodies; yet these few elements are so variously united, and combined with such endless modifications, as to form an exceedingly-complicated structure. This complicated nature gives rise to the endless changes described in the last article, and to ever-varying phenomena, beginning with the very dawn of existence, and continuing through infancy, childhood, youth, and age—through health and sickness—through youth, maturity, and decay, even to dissolution.

21. *They consist of both solid and fluid substances.*—Mineral matter is generally either entirely solid, or entirely liquid, or entirely gaseous; but organic bodies are made up of suitable proportions of solids and liquids, with gases interspersed. A mass of mere fluids could perform no mechanical motions; while, in a solid mass the functions of life could not be performed. In animals there is a constant

tendency to the decrease of the fluids and the increase of the solids. The young have a much larger proportion of fluids than the aged. In extreme age the cartilages are changed to bone, and many of the soft and flexible parts become hard and rigid. From this cause, were there no other, death would result.

22. *Origin of organic bodies.*—Organic bodies derive their origin from individuals already existing, and the species is constantly perpetuated by the process of generation. No essential change or modification occurs. Like produces its like in uninterrupted succession. Inorganic bodies present an order of things altogether different. The elements of which they are composed, when placed in favorable circumstances, will always combine according to the laws of affinity; and frequently new bodies, altogether different from those before known or ever existing, may be formed. The chemist may thus produce, in his laboratory, nearly all the compound bodies of nature. He can even make compositions which were never found in nature. He can produce gaseous, liquid, and solid bodies. The imponderable agents—even lightning itself—come and go at his bidding. But he cannot make an organized being. He may know all about its composition; he may ascertain all the elements of which it is formed, and in what proportions they exist; but he cannot himself combine the elements and produce the being. Should he succeed in producing the form, he would still lack the Promethean fire necessary to give it life. He cannot place within it that principle of self-motion, so different from all mechanical force, by which animals live, and grow, and move.

23. *Mode of growth.*—Organic bodies differ much from inorganic in the mode of growth. They always, after the commencement of their existence, increase, according to specific laws, until they reach a certain limit, which they can never pass. The increase proceeds from the interior,

by means of certain juices, which the organs prepare and continually renew from the aliment, which is presented from without. These juices circulate through the whole system, penetrate all the parts of the body, and deposit in each part particles of matter, which the organs, by new modifications, assimilate to the living matter already existing. Each interior part thus dilates gradually, and is increased in all its dimensions; and, by this means, the exterior volume of the body is successively augmented.

Inorganic bodies do not necessarily increase, after the first commencement of their existence. If they, in particular cases, do, the increase is always from without, by the aggregation of successive layers; nor is there, necessarily, any limit. The same cause which induces certain particles to collect around a nucleus, would, if it continued to act freely, and matter sufficient were furnished, successively lead other similar particles to group themselves around the body. The mass might become more voluminous, in proportion as the number of particles is augmented. The growth might be suspended for a long or a short time, and again commence, if new matter be furnished.

24. *All organic beings die.*—Minerals are never said to die. They may disintegrate and crumble to pieces. They may change their form. They are liable to changes, and even decomposition, having no inherent power to resist the action of heat and cold, and the action of decomposing agents; but they never lose their characteristic and distinctive properties. They are mineral substances still, and may be recomposed and recombined. A beautiful piece of ice, which you may often find on a winter day, may be broken, and reduced to small fragments, and melted to water, and then resolved into oxygen and hydrogen gas; yet the same gas may be recombined in water, and the same water rearranged in the same beautiful crystal.

But organized bodies must, from the very nature God has

given them, die. For their appointed time they are capable of resisting the action of physical agents. They maintain a temperature of their own, independent of surrounding bodies. They have the means of repairing any accidental injury, and replacing the wear and tear. But they have their bounds, which they may not pass. Decay at last becomes more rapid than repair, and ultimate dissolution is inevitable. Melancholy seems the doom of all living beings. The annual plant lives but a single season, and dies. The oak and the elm may live for many years, but die at last. Of animals the period of life is various, but, in every case, limited to a few years, or, in the longest-lived animals, a century or two.

The beautiful forms of nature, how soon they perish! The lovely flower blooms for a day, composes itself for sleep at night, and wakes no more. The bright and beauteous being to-day is buoyant in childhood, but to-morrow dies, and is laid in the earth. Yet we should not complain of this law of nature. Mortality is the condition on which it pleases the divine Being to give life to all creatures of earth. In the present order of things, death is as natural as life. To it all must yield. You and I must go the way of all the earth, and all that live hereafter must follow us.

25. *Classification of organic bodies.*—Animated beings are naturally divided into two classes—vegetables and animals.

26. *Resemblances between plants and animals.*—The general resemblance between plants and animals may have gleamed out from our remarks on organic bodies, inasmuch as the subjects of both the vegetable and animal kingdom have each alike all the distinguishing properties of organic natures; but there are still a few more particular resemblances, which we now proceed to notice.

27. *In the mode of their origin.*—We have already observed, (§22,) that all organic beings are produced from

creatures, similar to themselves, previously existing. There are, however, interesting resemblances in the particular manner of production. These will the more clearly appear from a comparison of plants with oviparous animals. The egg of the bird, and the seed of the plant, contains, each within its external covering, the germ of the future being. Under favorable circumstances this embryo becomes developed. The necessary circumstance is the presence of heat and moisture. The seed obtains its heat from the sun, and its moisture from the earth. The egg derives its heat from incubation of the mother bird, and its moisture from its own resources. Subjected for the requisite time to the influence of heat and moisture, the plant from the seed, and the bird from the egg, burst the external covering, and are admitted to the enjoyment of light and air, and to the rights and privileges of independent existence. Each, however, is for a brief period incapable of obtaining its own food, and some provision is necessary for its temporary subsistence. And this provision is similar in the two cases. In most kinds of seeds, the main body, the meat of the seed, undergoes in the ground a change from a solid, compact substance, to a sweetish liquid. This liquid is peculiarly nutritious, and by it the young plant is nourished until it becomes able to draw its own nourishment from the soil. When the young bird is hatched, it has inclosed in its shell the yolk of the egg, which serves it for sustenance until it can pick and digest the food peculiar to its species.

28. *In the functions of their organs.*—It has been observed (§17) that organic beings are distinguished from inorganic, by the possession of certain organs and instruments, designed for the preservation of the individual or its species. It is wonderful how the organs of plants resemble, in structure and function, the corresponding organs of animals. The bark of the tree consists of the same number of coats, and answers the same purpose as the skin of

animals. Inasmuch as all organic beings require air for their support, plants as well as animals have organs of respiration. The leaves of trees accomplish the same design as the gills of fishes and the lungs of animals. Organs of circulation are equally found in both animals and vegetables. In animals the blood circulates from the heart, through the arteries, to every part of the body. It is then carried by the veins back to its source—the heart—and thence, after renewal and purification, over the body again, carrying nourishment to every part of the system. In trees the sap is the blood, and it circulates in the system in a similar manner, through similar vessels, and for the same purpose, as the blood of animals.

29. *Distinction between plants and animals.*—Most writers on natural history make locomotion the distinctive characteristic of animals. But, should we attempt to apply this rule in practice, we might, in some cases, mistake an animal for a plant, or a plant for an animal. Some species of animals never remove from the rock or the spot of earth on which they happen to be fixed. On the other hand, some plants have no fixed roots, but float about the sea, receiving nourishment from its waters. The sensitive plant, though it has not the power of locomotion, yet has, in an eminent degree, that of moving parts of itself. On the slightest touch it seems to recoil. You have also noticed that the stem of a plant always grows up, and its root down—that it always grows toward the light, and some species always turn their flowers toward the sun. These motions are surely not less remarkable than the slight motions of the lower orders of animals.

30. *All animals have a stomach.*—There is, indeed, only one plainly-marked characteristic difference between animals and plants. This is found in the possession of a stomach and a digestive apparatus by animals, and the total absence thereof in plants. The food of plants is exceedingly simple,

consisting of a very few of the inorganic elements. No complicated digestive apparatus seems necessary for the conversion of the elements into organic compounds. But the food of animals is more complex. They cannot live on inorganic matter.

It is only after the elements have been elaborated and assimilated by the organs of vegetables, that they become suitable for the support of animal natures. Inasmuch, therefore, as the food of animals is more complicated and various than that of plants, the former need and have a more complicated and varied digestive apparatus. This consists, in the simplest possible case, of a stomach. Every animal, however poor, owns a stomach. In some cases he has nothing else but a stomach, and a single opening into it. When he has filled it with food, he waits until it has extracted all the nutriment, and then he turns himself inside out, empties his stomach of the excrement, and fills up again. In the higher order of animals the digestive apparatus becomes very complicated, and exhibits wonderful design, which we may notice hereafter.

31. *Classification of animals.*—Having ascertained the characteristic distinction of animals, we now proceed to their classification. Philosophers have formerly been in the habit of proposing each his own method of classifying animals; but all other systems seem now giving way to that of Cuvier, which is remarkable for simplicity and beauty. The following is a brief synopsis of Cuvier's system, somewhat modified.

32. *Invertebral animals.*—All animals, from the smallest animalcule up to man, are arranged in this great division. The distinction is founded on the presence in the animal, or the absence, of a bony frame-work or skeleton. Inasmuch as the backbone is the most important part of the skeleton, and *vertebra* in Latin means a backbone, animals having a skeleton are called vertebral, and those destitute of it,

invertebral. The invertebral animals are divided into five classes.

(1.) Zoophytes.—This class is lowest in the scale, and includes such animals as the animalcule, sponge, polype, and sunfish.

(2.) Vermes, or Worms.—This is second in the ascending scale, and includes the whole family of worms.

(3.) Mollusca.—This class embraces those having a soft body in a hard shell, usually called shell fish, such as the oyster and clam.

(4.) Crustacea.—This class has a crusty shell, and includes all such as the lobster and crawfish.

(5.) Insects.—This is a very extensive, interesting, and well-known class.

33. *Vertebral animals*.—This division is arranged in four classes, and each class in several orders.

(1.) Fishes.—This class is well known, and includes a great variety of species.

(2.) Reptiles, including four orders—as the Chelonia, or tortoise order; the Saurian, or lizard order; the Ophidian, or serpent order; and the Batrachian, or frog order.

(3.) Birds, comprehending six orders—as the Accipiters, or hawk order, including all birds of prey, such as the eagle, hawk, and owl; Sparrow order, including an immense variety; Climbing order, including such as the woodpecker and parrot; Gallinaceous order, including the common hen, turkey, and pigeon; the Waders, including the crane, ostrich, and plover; and the Web-footed, including the pelican, gull, goose, and duck.

(4.) Mammalia.—This is the highest class. It includes all animals that bring forth their young alive, and nourish them with milk. The name is derived from the Latin word *mamma*, signifying, *that which affords milk*. This important class is divided into nine orders. The orders are, 1. The Marsupial, including the kangaroo and opossum. 2. The

Cetaceous, including the whale and dolphin. 3. The Pachydermata, or thick-skinned, including the elephant, rhinoceros, horse, and hog. 4. The Ruminating, or cud-chewing, such as the camel, deer, ox, sheep, and goat. 5. Toothless, such as the sloth, armadillo, and ant-eater. 6. The Gnawers, such as the beaver, squirrel, rabbit, rat, and mouse. 7. The Carnivorous, such as the tiger, lion, dog, cat, wolf, and bear. 8. The Four-handed, including all the varieties of apes and monkeys. And, lastly, the Two-handed, including only *man*, who stands at the head of the list, the lord of creation, the noblest of God's terrestrial creatures.

We have thus gone through with what may be considered the introductory part of our work. Be not discouraged at the hard names we have been obliged to introduce in our descriptions and classifications. It is impossible to give, as we have tried to do, a perspicuous synopsis of natural history, without using terms and names which may be new to you.

We are now prepared to go on with our design; and I trust you will be more interested with the succeeding, than you could be in this dry part of the course.

LECTURE III.

STRUCTURE OF THE HUMAN BODY, AND INDICATIONS OF DESIGN THEREIN.

Structure of the human body—Synopsis of the skeleton—Design of the skeleton—Composition of bone—Phosphate of lime—Adaptation thereof to the purposes of bone—Covering of the bones—Wanting in the teeth—Sensibility of bone—Final cause of sensibility—Pain not a punishment—Joints—Bones of the skull—Design of the skull—Protection of the brain—Bones of the face—Connection of the head with the trunk—The spine—Design thereof—Security against dislocation—A wise provision—Curvature of the spine—Bones of the arm—Joints at the elbow and wrist—Bones of the hand—Design of the chest—Protection of the lungs—Provision for their action—A caution—Connection of the chest with the upper extremities—The shoulder—Connection of the arm with the shoulder—Wisdom of the contrivance—Bone of the arm—Bones of the pelvis—Bones of the lower extremities—Special provision at the ankle—Kneecap—The foot—Design of its arch—Special contrivances at the joints—Cartilage—Synovial fluid—Provision for the passage of nerves and blood-vessels—Protection against dislocation.

34. *Structure of the human body.*—Having noticed the general properties of matter, the distinctions between organic and inorganic matter, between animals and vegetables, and the method of classifying animals, we will proceed to describe the structure of man, the highest order of animals—to explain the benevolence of the design, and exhibit the marks of wisdom in the execution of the work.

35. *Synoptical view of the skeleton of man.*—The skeleton of the human body is composed of about two hundred bones. For the convenience of description, they are generally classed as bones of the head, bones of the trunk, and bones of the extremities.

The bones of the head are twenty-three—being eight of the skull, fourteen of the face, and one of the tongue.

The bones of the trunk are fifty-one—being twenty-six bones forming the spine or backbone, twenty-four ribs, and the sternum, or breastbone.

The bones of the upper extremities are sixty-four—thirty-two on each side—being bones of the shoulder, of the arm, and of the hand.

The bones of the lower extremities are sixty—thirty on each side—being bones of the pelvis, of the thigh, of the leg, and of the foot.

36. *Design of the skeleton.*—The bones forming the skeleton of man answer three purposes:

(1.) They furnish a firm support for the system, and a frame-work, by which the body maintains its determinate shape. (2.) They serve as means of locomotion, being used as bases for the attachment of muscles, and levers for economizing power. (3.) They form a protection for the delicate and vital organs of the system.

37. *Elementary composition of bone.*—The principal ingredients of bone are only two—gelatine and lime. Gelatine is an organized animal substance, probably well known to you under the name of glue. Bone is one-third gelatine, and two-thirds lime. If you boil a bone for a long time the gelatine will boil out, and the lime alone remain. In this state the bone has no toughness, but will easily break and crumble to pieces. The gelatine may be the more effectually expelled by exposing the bone to a slow fire. The substance left will retain the general appearance of bone, but will crumble to pieces from the slightest pressure. On the other hand, if you place bone in nitric acid, it will lose all its lime, and with it all its firmness, and become flexible as a rope. In this case the lime is extracted by the acid, and nothing is left but gelatine.

In children the gelatine predominates, and the bone is limber, and may be easily bent without breaking. In old people the lime predominates, and the bone is easily broken. The gelatine and lime both exist in our food, and are furnished for making bone by the blood.

38. *Peculiar kind of lime in bone.*—There are several

kinds of lime, as chloride of lime, frequently used in removing offensive odors, sulphate of lime, known under the name of gypsum and sometimes plaster of Paris, carbonate of lime, being common limestone, and phosphate of lime, which is the kind used in the composition of bones. There is wisdom exhibited in this selection. The common lime is used in the formation of the shells of the crustaceous animals, but it is not so well adapted to the purposes of bone as is the phosphate.

39. *Well adapted to its purpose.*—(1.) The development of the human form requires that the bones should be susceptible of vital organization and of growth. Did not bones possess a high degree of vitality, having vessels of absorption and nutrition, the dead parts of fractured surfaces could not be removed, and new matter deposited; and hence bones broken by accident could never be united again. Now, common lime, or, to use the scientific term, carbonate of lime, seems not adapted to organization. The shells of crustaceous animals, composed of common lime, never grow. When the body within the shell has grown so as to get crowded for room, the animal sheds his shell, and has to hide away, defenseless, until the organs on the skin deposit a new shell. But phosphate of lime, wherever it occurs in animals, is highly organized, and capable of development and growth in proportion to other organs of the body.

(2.) Phosphate of lime is much firmer, stronger, and more substantial than carbonate. It is far less brittle and liable to decay.

The wisdom in choosing, between the various kinds of lime, the phosphate, appears the more wonderful, when we reflect that phosphorus, one of the elements of phosphate of lime, never exists naturally in a separate state. Indeed, phosphorus itself is of very little consequence in nature or in art, but in combination with lime forms, as we have seen, a most important part in the human system.

40. *Covering of the bones.*—Over every bone, except the teeth, which, though bony substances, are not considered permanent parts of the skeleton, is a thin covering, called the periosteum, from two Greek words, signifying, *about the bone*. Its use is to conduct the nutritious vessels and nerves into the substance of the bone.

41. *Reason why this is wanting in the teeth.*—In the teeth the periosteum is wanting, and its place is supplied by enamel, the hardest of all animal substances. The periosteum would soon have worn away on the teeth, but the enamel, which is principally phosphate of lime, with a very small portion of gelatine, is so hard that neither saws nor files produce much impression on it.

42. *Sensibility of bones.*—In a condition of health the bones are totally insensible. They may be cut or sawed without causing pain. But when they become diseased and inflamed they are exquisitely sensible.

43. *Final cause of sensibility.*—It would appear that the sensibilities of the living body are not qualities necessarily arising from life, for many parts most highly endowed with vital energy are wholly insensible to external impressions. The heart itself may be handled without causing pain. The brain, too, may be mangled, and cut, without the least consciousness of the patient. Sensibility is an appropriate endowment to each part of the living frame, suited to the degree of exposure, and designed for its protection. The heart is so situated as to be generally secure from external injury. It is, therefore, not endowed with sensibility to touch. It is, however, keenly sensible to every variation in the circulation, and is in the strictest sympathy with the affections of the mind. The brain is so protected by the skull as to be out of the way of external violence. It is only the membranes covering the brain that are endowed with that keen sensibility which is sometimes exhibited in diseases of that organ.

The bones are so situated as not to need any protection from outward violence. Therefore, they are made insensible to it. But when, by accident, they become broken, and their texture destroyed, sensibility becomes their kindest guardian, and the surest promoter of their recovery. It becomes their guardian by securing the quiet indispensable to the reunion of the parts, and the promoter of their recovery by increasing the excitement and stimulus necessary to promote the work of restoration.

44. *Pain not a punishment.*—We see, in these examples, as well as in numerous others, that, in the present order of things, pain is designed, by the great and good Being, not as a punishment, but as a merciful contrivance for the protection of the part affected. Were not we sensible to painful impressions from external violence, the corporeal system might be ruined before we were aware. Did not the extremes of heat and cold give us pain, the delicate texture of the body might be destroyed before we should apprehend danger. Were not the incipient stages of fever attended with pain, incurable disease might creep on us at every step.

Here, then, we see that very susceptibility to suffering, of which we so much complain, proving to be a merciful endowment, designed in benevolence, and executed in wisdom, for our protection. It thus often happens that what we deem curses, turn out to be blessings. The susceptibility of the human body to acute pain has often been urged against the goodness of God. Erring human nature is apt to mistake its friends for its enemies, and to see malevolence and cruelty, where nothing but kindness and mercy were meant.

45. *The joints.*—One great purpose of the bones—the furnishing us means of locomotion—would be defeated, were it not for the joints connecting one bone with another. There are several kinds of joints. The most important are

the hinge joint, and the ball and socket joint. The hinge joint is designed for motion backward and forward, in the same line. A good example of it may be observed in the knee. The ball and socket joint is designed for a kind of rotary motion, free in every direction, such motion as is required at the hip and the shoulder. To form this joint, the end of one bone is shaped into a round head, or ball, and this is received in a corresponding socket, or cup-like cavity in the other bone.

We shall see, as a mark of divine wisdom, that each of these joints is placed just where it is wanted—the hinge joint being never found where motion in every direction is needed, and the ball and socket never where simple swinging motion is required.

Having thus noticed the general properties of the bones, we proceed to describe more particularly the bones of each part of the body, their specific use, and the manner in which the end is accomplished.

46. *Bones of the skull.*—Lay your hand upon your own head, or examine the head of another, and it may appear that the skull consists only of one bone. But there are eight distinct bones in the skull. These are united by a peculiar kind of joint, called a suture. This word implies that the bones appear to be stitched together. The appearance of the joint is much like that which might be formed by putting two saws together, teeth to teeth. With such a joint as this, the more pressure there might be on the skull, the more firm would be the grip of the joint.

Each of the eight bones is double, having an external and internal plate. The external plate of the bone is fibrous and tough. The internal is hard and brittle. These two plates are separated by a cellular membrane, called the diploe.

47. *Design of the skull.*—The skull answers no purpose of locomotion. It does, however, give shape and beauty of

form to the head. By differences in the form of the skull, man is distinguished from other animals, and the various races of men from one another. The Caucasian, or European race, is distinguished by the beautiful oval shape of the head, and the large, full forehead; the Mongolian, or Asiatic, by the depressed and retreating forehead; and the African, or negro, by the narrow and flattened forehead. But the chief design of the skull is to protect the brain, the most delicate and essential organ of the human system. In order to see the wisdom of the design, and the skill of its execution, it will be well to ascertain the kind of injuries to which the brain, from its constitution and position, might be liable.

48. *How the brain might be injured, and how it is protected.*—(1.) The brain, like all other vital organs, might be injured by sharp bodies touching and lacerating it. This injury is so effectually prevented by the hardness and thickness of the skull, that accidents of this kind seldom occur in human life.

(2.) But the most frequent and fatal injury, to which the brain might be exposed, is from blows and jars, producing concussions. A jarring, concussion, or vibration through the substance of the brain, would more effectually deprive a man of sense, of motion, and of life, than would the cutting through it with an ax or sword. Falls and blows are, therefore, peculiarly dangerous.

It would seem difficult to provide a covering, which should at the same time afford protection against external wounds and internal concussions. A soft covering would prevent jarring, but would not keep off sharp instruments. A hard covering would protect against laceration, but, from its liability to ringing and vibration, it might communicate concussion to the delicate texture of the brain. A hard substance, however, had to be used, and we will see how admirably the effect of vibration is prevented.

We have already seen (§46) that the skull bones consist

each of two plates, separated by a soft, spongy tissue, called the diploe. The outer plate is tough and fibrous; the inner is hard and brittle. This inner plate, or table, is so hard, that a blow on it direct would cause it to ring like a bell. But, in addition to the fibrous outer bone, and the spongy diploe, by both of which the force of the blow would be much deadened, there is a membrane like a piece of cloth, or leather, lining the outside of this inner table, so as effectually to arrest any vibration which may have passed through the outer protections.

Now, suppose you had a very delicate substance inclosed within a bell. The vibration of the bell from blows would jar and ruin the sensitive organ; and your object is, by some means, to prevent the effect of concussion. You might first cover the outside of your bell with cloth, or leather. Then you might put over this a layer of porous, spongy matter, like rotten-stone. Over all you would put a covering of tough, fibrous wood. A blow would be received, first, by the wooden covering; then by the spongy substance beneath; then by the cloth spread over the bell. By all these contrivances the force of the blow, by the time it reached the bell, would be effectually deadened, and little or no vibration or jarring would be communicated to your delicate structure within.

Such is the arrangement for protecting the brain. First comes the tough, fibrous bone beneath the scalp; then the spongy diploe; then the lining membrane, called the dura mater; and lastly the inner layer of bone. Within this inclosure, thus guarded and protected, the brain is securely lodged.

How admirable is the wisdom of these contrivances, and how exquisite the skill of execution! Surely there is a God; and he is an omnisciently-wise and an infinitely-good Being.

49. *Bones of the face, and their use.*—The principal

design of the bones of the face—fourteen in number—is to give shape and beauty to the countenance. There is, indeed, on earth nothing so beautiful as the human face. No wonder the poet calls it *divine*. Much of its beauty depends on the perfect symmetry and exquisite contour of the shape, and the shape is dependent on the arrangement of the bones. A skillful mechanic might, without much difficulty, fashion a block, or single piece of wood, into a regular shape; but he would find it very difficult, if not impossible, to form fourteen separate pieces of wood into a figure perfectly symmetrical; and still more, to form thousands of figures, all of the same general shape, yet all easily distinguished, one from every other. Yet the great Architect of nature has been doing this for ages, with scarcely a single deviation from perfection. And if a slight departure from perfect symmetry may sometimes be discovered—if a face may be found crooked, awry, or in any way ill-shaped—it will be uniformly found owing to some accidental cause, either congenital, or the result of external violence after birth, or, in some cases, the effect of disease.

50. *Connection of the head with the trunk.*—There are, connecting the head with the trunk, two joints, which, in their form and uses, exhibit much wisdom.

The head rests upon the backbone, or spine, which consists of more than twenty different bones, called *vertebræ*. The head is joined to the upper vertebra by a hinge joint. This allows of motion backward and forward, as in bowing, nodding, locking downward or upward. Without such a joint a man must always appear stiff-necked and high-headed. Between the first and the second vertebra is a species of ball and socket joint. The upper bone has a little cavity on its lower side. The second has a little projection, like a tooth, corresponding to the cavity above, and entering into it, forming a pivot, on which the head turns freely in a circle, as far as the muscles will allow, and,

indeed, as far as necessity or convenience requires. When you look up or down, you use the upper, or hinge joint; and when you look around, you use the lower, or ball and socket, or pivot joint. Here appear mechanical contrivance and very great wisdom, all designed for the happiness and convenience of man.

51. *The spine, or backbone.*—This is composed of twenty-six distinct bones, piled one above another. Each bone is called a vertebra, and the whole together the vertebral column, from the Latin word *verto*, to turn, because the body turns round this column as an axis. Every vertebra is a symmetrical ring. You will have a good idea of it, by supposing a round stick of timber bored through, as for a pump, and then sawed into twenty-six pieces. Each piece will be a ring, with a hole in the centre. Take, then, any two pieces, and cut a notch on opposite ends of each piece, so that when the pieces are placed in contact the notch in the upper shall correspond to that of the lower piece, forming a round aperture. To finish the article, you would need to whittle away the middle of each piece, so as to leave the upper and lower edges broader than the intermediate part, and put on the edges some horns or projections for the attachment of strings to fasten the pieces together, and you would have a rough model of the vertebræ.

But you might understand the matter much better, by examining the spine of any animal whose carcass has decayed in the fields.

52. *Design of the spine.*—The spinal column is intended to effect all three of the purposes described in section 36.

(1.) It affords support to the entire skeleton, being the great central beam of the fabric, establishing points of union between all its parts, and combining them into one continuous frame-work. Its firmness and strength are secured by means of the broad bases of the vertebræ, and the closeness of their junction, the one to the other.

(2.) It is the general axis of all the motions of the body, and the common fulcrum on which the bones of the extremities are made, like levers, to turn. It also furnishes, by its projections and processes, attachments by which all the large muscles are fastened. To accomplish these purposes, it should be not only firm and strong, but flexible. A stiff, rigid column, without joint, might be strong, but never would answer the purposes of motion. To secure flexibility, and motion as a result of flexibility, the column is made to consist of a great number of separate pieces, united by elastic cartilage. Each joint yields a little, and all, together, allow as much motion as is necessary.

(3.) It is designed for protection and passage to the spinal marrow. The delicate substance to which the spine furnishes protection is called spinal marrow. The spinal marrow proceeds from the brain, and is, in composition and substance, very similar to that organ. The security of the spinal marrow is essential to life. Pressure upon it paralyzes all parts of the system below the point of pressure. To protect it in its passage down the body, the spine forms a continuous tube, surrounded by firm bone. As we have seen, each vertebra has a hole bored through the middle, in such a manner that, when they are put together, the hole in one bone falls into a line, and corresponds with that in the bone above and the one below, so that the perforated pieces, when joined, form one entire and uninterrupted channel.

But the spinal marrow is the source of the nerves of feeling and of motion, and it is necessary that passages should exist for the giving out of nerves all along the column, in order to supply the different parts of the body. For this purpose the notches mentioned before, (described in section 5,) are designed. When two vertebræ are put together, the notch in the upper just fitting that in the lower, there is formed a small hole, through which the nerves at each

joint go out in pairs, one on each side, in order to send branches to every part of the body.

53. *Security of the spine against dislocation.*—From the delicate nature, and essential use of the spinal marrow, dislocation of the spine must prove fatal. If the dislocation occur in the neck, called breaking the neck, or anywhere above the point where the nerves issue from the spine to the heart and the lungs, immediate death inevitably results. But if the injury occur below the vital organs, the sufferer might live for a time, but could never move the parts of the body below the fracture. Security, therefore, against such accidents must be obtained. This is accomplished by the broad surfaces of the vertebræ; by the strong ligaments which bind them one to the other; by the mutual interlocking of the projecting portions, or processes; and, by the peculiar mode of articulation between them and the ribs, each rib being united not entirely to a single bone, but partially to two contiguous vertebræ, near their line of junction.

54. *Another special provision.*—At each interstice, between the vertebræ, there is a peculiar, gristly substance, which may be squeezed out from between the bones. This gristle permits the bones to play a little in the motions of the body. It is inclosed in an elastic binding, or membrane, of great strength, which passes from the edge or border of one vertebra to the border of the one next to it. When a weight is on the body the soft gristle is pressed out, and the membrane yields. The moment the weight is removed the membranes recoil, by their elasticity, the gristle is pressed into its place, and the bones resume their position.

The design of this contrivance is, (1.) To aid in allowing free and easy motion of the parts of the body; and, (2.) To prevent jars to the spinal marrow and brain. Were it not for the interposition of this elastic material, every motion of the body would produce jarring of the brain, and we should suffer as much in alighting on our feet as in falling on our head.

55. *Design of the curved form of the spine.*—If a steel spring, perfectly straight, be pressed between the hands, it will resist; and when it does give way it will be with a jerk. Such would be the effect on the spine, if it stood upright, one bone perpendicular to another; for then the spine could yield neither to the one side nor to the other. Every motion, then, would produce a painful jar. The spine, however, is not upright, but curved, something in the shape of an italic *S*, and thus forms a most perfect spring, admirably calculated to sustain the head, without jar or injury of any kind.

We may feel the importance of this structure, and appreciate the benevolence of the design, by observing the painful jar experienced on stepping into a place lower than we expected. When we walk on level ground, the spine maintains a uniform curvature. When we step deliberately down stairs, we prepare for the descent by changing the curvature. But when we happen to step down suddenly, and unexpectedly, we do not provide for the necessary change, and therefore we suffer from the jar. Another illustration of the importance of this arrangement may be drawn from the condition of old age. The spine of age is more rigid than that of youth. Should, therefore, an old man fall with his head on the carpet, the blow, which would be harmless on the elastic frame of childhood, might to him prove fatal. Often, in age, the rigidity of the spine makes every step jar on the head. We thus see how many purposes the backbone of man is designed to accomplish, and how wisely these designs are effected, and how much the happiness of man is promoted by such wise and skillful contrivances.

56. *Bones of the fore-arm.*—There are two bones of that part of the arm between the elbow and wrist, lying along side of each other nearly parallel. The outer one, next the thumb, is called the radius, because it has been compared to the radius, or spoke of a wheel. The other, on the inner or under side of the arm, is called the ulna. The design of

furnishing the lower part of the arm with two bones, will be more clearly seen when we examine the joints at the elbow and wrist.

57. *Joints at the elbow and wrist.*—At the elbow the ulna is joined to the arm, or humerus, by a most remarkable hinge joint. It is, indeed, a real hinge. This allows a remarkably free, swinging motion, at the elbow. At this joint the radius, or outer bone of the arm, is not directly joined to the humerus, but it is allowed to turn freely within a cartilaginous ring. Thus there are two motions provided for at the elbow—a swinging, and a rotary motion.

At the wrist the other bone, the radius only, is joined to the hand—the ulna having no share in the connection. The joint here is a very curious one, being a compound of the ball and socket and the hinge. Now, to see the use of this complication of joints at the elbow and wrist, just try the experiment, and see what varied motions you can make, by means of the joints with the hand. Letting your arm hang at your side, with the palm of the hand directed forward, first raise your hand, by bending the elbow, keeping the wrist stiff. This elbow motion is performed by the joint of the ulna with the upper bone of the arm. Next, still keeping the wrist stiff, you may bring your thumb toward your body, so that the hand shall stand edgewise. This is effected by a rotation of the radius at the elbow. A motion at the wrist may now be made, by which the palm of the hand can be turned downward.

Such is an attempt at description of the mechanism designed for the motions of the hand. It is difficult to give a good verbal description of the action of these peculiar joints. But by making the attempt on yourself, you may discover the wonderfully-varied motions of which your arm and hand are capable.

58. *Bones of the hand.*—There are no less than twenty-seven bones in each hand, so arranged and articulated with

each other as to form the most curious piece of mechanism, perhaps, in the universe. What may not the hand of man accomplish! How delicate its structure! how adapted to all the exigencies of human ingenuity! With it man procures the food to support him, and weaves the garment to cover him. With it he brings sweet music from the lyre and the lute, and transmits knowledge to future generations.

59. *Design of the chest.*—The bones of the chest, being the breastbone and twenty-four ribs, are designed for the protection and action of the lungs. In order to understand the structure of the chest and its use, you will please examine your own form. Place your finger on any one of the longer ribs, at the point where it articulates, or joins to the spine. Tracing the direction of the rib, you will find it pursuing a curved course, inclining downward, so that the end joined to the breastbone is lower than that at the spine. In front you will feel the breastbone, called the sternum, extending from the neck to the pit of the stomach. To this bone the ribs are joined. The shape of the bones of the chest is such as to form, for the protection and play of the lungs, a spacious cavity.

60. *Protection of the lungs.*—The lungs being of delicate structure, and highly susceptible of inflammation from injury, require protection from external violence. The ribs, therefore, which serve for their protection, should be guarded against fractures; but their slender form and brittle substance would render them easily broken. To remedy the evils of this lightness and fragility of texture, which seem necessary to the beauty and easy motions of the body, the ribs are not joined directly to the breastbone, but there is interposed cartilage, or gristle, softer than bone, and very elastic and yielding. The front end of each rib is eked out, and a piece of cartilage, corresponding in form to the rib, so as to complete its arch, extends from the rib to the breastbone. This substance is better adapted in this place

than bone could be, to yield to the shocks, and rubs, and jolts, and motions to which the body is constantly liable. The elasticity of the cartilage recovers from the shocks which might otherwise break the ribs. When we lean forward, or to one side, the ribs accommodate themselves to the motion, not by any change in the bony part, but by the bending, or elasticity, of the cartilaginous termination. A severe blow on the ribs does not break them, because their extremities recoil, and yield to the violence.

By this arrangement, not only are the ribs secured against fractures, but the vital organs are protected against vibrations and concussions. A jarring vibration, or concussion, of the chest produces very unpleasant sensations, and might be seriously injurious. If each rib was a complete semicircle of bone, extending from the spine to the sternum, every blow, or slight jolt, would produce a ringing vibration through the whole chest. The interposition of cartilage greatly diminishes these effects, and secures us against constant liability to danger. You have heard of the man who imagined he was made of glass, and who was afraid to move, lest he should break all to pieces. Were it not for the wise and benevolent provisions which the great and good Being has made for the protection of the brain and the lungs, we should be constantly in as much real danger as the hypochondriac imagined himself to be.

61. *Provision for the action of the lungs.*—The lungs are of a light, porous substance, something resembling sponge. When the air is expelled they lie closed, or collapsed, like a dry sponge. When filled with air they are greatly enlarged, like a sponge saturated with water. That the lungs should alternately expand and contract is essential to breathing, and breathing, you know, is essential to life. But the lungs have no active power to expand and contract of themselves. Their action is mechanical, or, in other words, they are passive organs, operating only as they are

acted on by mechanical agencies. The lungs always retain more or less air, and it is the nature of air to occupy every unappropriated space. The lungs, therefore, are always expanded by the air in their cells, to such a degree as exactly to fill up the cavity in which they lie. Breathing is effected by the alternate increase and diminution of the capacity of this cavity. The cavity of the chest is first enlarged. This leaving more room for air, the lungs become expanded to the full extent of room by the rushing in of the external air. This is seen in inspiration, or drawing in the breath. Next the chest is diminished in space. This produces expiration, or breathing out. It is not the rushing of the air into the lungs which causes the enlargement of the chest, nor the rushing out which causes contraction; but the chest first enlarges, and then the air rushes in, just as it does into a bellows, when you pull the sides apart; and next the chest contracts; and then the air is forced out of the mouth, just as out of the nozzle of the bellows, when you bring the sides in contact. The only difference, in this respect, between the action of the lungs and of the bellows, is, that in the lungs air is admitted and expelled by the same opening—the throat—while in the bellows there are two openings—one for breathing in, and the other for breathing out.

From this reasoning it will appear that the chest should be so constituted as to admit of alternate enlargement and contraction. This object is secured, to a certain degree, by the direction in which the ribs run from the spine to the sternum. By examining your own ribs you will easily perceive that no one forms a right angle with the spine. They all run oblique, sloping downward. The consequence of this is, that, when they are moved, whatever pulls them upward, at their anterior extremity, necessarily draws them forward. A motion, then, of the ribs upward, bringing them to a right angle with the spine, would enlarge the

capacity of the chest, and let the air in; while the return motion downward would contract it, and force the air out. You will perfectly comprehend this, by placing your hand on your breast, and taking a few long breaths. You will perceive the whole anterior portion of the chest, ribs and sternum, even to the collar-bone, pressed upward and outward, as you take a deep inspiration, and dropping back to the natural position, as you make an expiration. Were not the ribs joined to the spine, in such a manner as to admit of the inclined direction in which they naturally lie when at rest, this enlargement could not be effected.

62. *Caution.*—Do not confine your ribs, nor in any way restrict the free, full play of your lungs. It is the worst species of suicide. If you will kill yourself, you had better choke yourself at the throat than at the lungs, and use a halter rather than corsets.

63. *Connection of the chest with the upper extremities.*—At the upper part of the breastbone you will find a little bone, extending to the shoulder. This is called the collar-bone. Its scientific name is clavicle, from its supposed resemblance to a key, which, in Latin, is called *clavis*. This is a very small bone, but of very great use. It preserves the square form of the chest, and affords free exercise to the hands. It keeps the shoulders apart from the chest, and throws the action of the muscles upon the arm-bone. It is not found in all animals, but seems appropriated only to such as require a lateral or outward motion. It is very strong in animals which dig or fly. In man it is perfectly formed, and adds to his mechanical power.

64. *The shoulder.*—The shoulder is made up of the clavicle and the shoulderblade, called *scapula*. The scapula is a very singular bone, appearing to be made expressly for its own purpose, and independent of the rest of the skeleton. Its use is to form a foundation-bone for the arm. Muscles are attached to it, and thence to the arm. It also

forms a centre and point of support for the muscles of respiration.

65. *Difference between the shoulder of man and woman.*—The breadth of the shoulders and the corresponding width of the chest in woman, is determined by the length of the collar-bone, thereby throwing the shoulderblade farther from the sternum. This is designed to leave room for the development of the organs of infantile nourishment. In man, broad shoulders and a wide chest are caused by the large size of the shoulderblade. The greater development of the scapula in man is designed to furnish him the foundation of that great physical strength in which he so much excels woman.

66. *Connection of the arm with the shoulder.*—The shoulderblade has in it a depression, or hollow, or a cavity like a shallow cup, in which is inserted the rounded head, or ball, of the arm-bone, forming what has been described as the ball and socket joint.

67. *Wisdom of this contrivance.*—The motions required at the shoulder are very various. Man needs to move his arm in every direction—up, down, backward, forward, and laterally. A hinge joint, like the one at the knee, would not answer the purpose at all; hence, wisdom is exhibited in furnishing a ball and socket joint at this place. The same kind of joint is found at the hip; but the cavity at the shoulder is much more shallow than that at the hip, and the ball much less firmly inserted. This allows of motions, at the shoulder, much more various, easy, and free than at the hip, but, at the same time, renders dislocation of the shoulder much more frequent than of the hip; but dislocations of the shoulder are easily reduced, and produce no permanent injury, while those of the hip are very difficult to restore, and often produce lameness for life.

There is one long bone, extending from the shoulder to the elbow. This is called the bone of the arm, and, in

anatomy, the *humerus*—the Latin name for shoulder. It is the longest and strongest bone of the upper extremity.

68. *Bones of the pelvis.*—The bones of the pelvis—a Latin word, signifying basin—are four, forming a cavity, in which are deposited some of the most important organs of the human system—organs, without which the species could not be perpetuated, nor the domestic relations, the highest and the holiest of our nature, exist. In woman these bones are so arranged as to give a much greater capacity to the pelvis than in man. The design of this, and the wisdom and benevolence therein manifested, are too obvious to the reflecting mind to need illustration.

69. *Bones of the lower extremities.*—The general arrangement of the lower extremities greatly resembles that of the upper. There is at the hip, as at the shoulder, a ball and socket joint. There is only one bone of the thigh, as of the arm. There is a hinge joint at the knee, as at the elbow. There are two bones of the leg, as of the fore-arm. The knee joint is capable of less variety of motion than the elbow, being principally limited to swinging or hinge-like motion, backward and forward, in the same line. A rotary motion at the knee would not only be of no use, but would be an absolute inconvenience, inasmuch as it would interfere with the stability of the joint required in standing or walking. For the same reason the joint at the ankle admits of less motion than that at the wrist.

70. *Special provision in the ankle joint.*—There is a beautiful contrivance to prevent dislocation of the ankle joint. From the position of this joint, the great weight it has to sustain, and the twists and wrenches to which it is constantly liable, in walking, running, and jumping, it would be greatly in danger of repeated dislocations, were there not special pains taken to prevent such a catastrophe. In order to this, the two bones of the leg project, at their lower end, below the ankle joint, forming two prominences, which you may

feel in your own ankle, one on the inside and the other on the outside of the leg. The upper bone of the foot is received between these projections, at a point so far up, that the ankle cannot well be dislocated, without breaking off the ends of one or the other of the bones of the leg.

A comparison of the wrist and the ankle, in man, shows that he was designed to walk upright. His hands have not, at the wrist, the strength and security of articulation necessary to support the body; whereas the joints of the upper and the lower extremities of the ape are equally adapted to walking. Man, then, was made, physically as well as morally, upright. He lost his moral, but retained his physical erect position. He, however, is the only animal designed for an upright position.

71. *Kneecap*.—There is a little bone, called, in anatomy, the patella, and in common language the kneecap, which we must notice, for its peculiarity and its use. It is circular, and, on the external surface, convex. On the inner surface there is a ridge, near the middle, and two slight depressions, or concavities, on each side, all exactly fitting the lower extremity of the thigh bone. The kneecap is movable when the leg is extended, but confined when the knee is bent. Its use is to protect the tendon and the joint of the knee from injury, and to aid the action of the muscles. It answers these purposes admirably.

72. *The foot*.—There are about twenty-six bones in the foot. The only point of curious interest, to which we need direct our attention, is the arch of the foot, formed by the ingenious arrangement of the bones. In a well-formed foot the toes and the heel only touch the ground. The middle portion of the foot never reaches the ground. The foot, indeed, forms a perfect arch.

73. *Design of the arch of the foot*.—The design of the beautiful, arched shape of the foot is to protect from the jolts and jars which would otherwise be inevitable, from

walking, running, and, indeed, all the movements of an erect being. When we walk or run, the heel first touches the ground. At this stage the bones of the leg are not perpendicular over the heel. If they were, we should receive a severe jar; but, as the bones are oblique over the first part touching the ground, and we bring gradually the toes to the ground, we descend in a semicircle, and the arch of the foot furnishes a spring. There is, indeed, as great a difference between jolting on an arched and a flat foot, as between the elliptical springs of the pleasure carriage and the no springs at all of the old mud wagon. If you ever saw a club-footed man, and listened to the thumping noise of his step, you might see how much we gain, in lightness and ease of motion, by the graceful arch of the natural foot. Of the spring of the foot you may become sensible, by deliberately walking up a flight of steps, and observing the elements of motion. We should be reminded, every step we take, of the wisdom and love of God.

74. *Special contrivances at the joints.*—There are, in the joints, some peculiar provisions which we have not yet noticed.

The first we will describe is a contrivance to diminish friction. Every one knows, that any motion of a machine must produce, at its joints, friction, retarding the movements, and gradually wearing away the parts coming in contact. Such would be particularly the case in the human body, where the articulating instruments are bone, were there not special provision to avoid it.

75. *Interposition of cartilage.*—The ends of the bones forming the movable joints are tipped with cartilage—a smooth, dense, elastic substance, admirably calculated to facilitate motion. Cartilage, in its intimate structure, consists of an infinite number of minute fibres, arranged perpendicularly, forming millions and millions of springs,

which stand perpendicular to the force applied, bend to the pressure, and, on its removal, regain, by their elasticity, their natural form. The interposition of cartilage, therefore, between the bones, at the joints, not only prevents the bones from grating on each other, but greatly contributes to the elasticity of the system. Is it not a mark of Divine love and wisdom, that cartilage should be placed where it is needed, instead of being scattered at random over the system, in places where, instead of beauty and convenience, it might constitute deformity, and prove an impediment to motion?

76. *Synovial fluid.*—The surface of the cartilage between the ends of the bones, at the joints, is not only, from its constitution, naturally exceedingly smooth, but it is lubricated by a fluid called *synovia*—a thick, viscous liquor, better calculated than oil for preventing friction. When inflammation occurs, this fluid is not supplied, and the joint becomes stiff, and the surfaces creak, like a hinge or wheel without oil.

Would he not be deemed a skillful mechanic, who should make a carriage, about whose axle there should be provision, not only for applying grease to the wheel, but also for making it as it might be wanted?

77. *Provision for the passage of nerves and blood-vessels.*—The nerves and arteries destined for the extremities must pass over the movable joints. In their passage they may, from sudden motions of the limb, and abrupt bendings of the joints, be in danger of injury from compression or laceration. To guard fibres so tender against effects so injurious, their path is protected with great care. At the knee the extremity of the thigh is divided into two heads, or prominences, with a depression between them. Along this depression, in this valley between two eminences, the arteries and nerves securely make their way. At the shoulder, in the edge of the cup, or socket, which receives

the head of the bone, is a notch, covered, at the top, by a ligament. This notch affords a safe passage for the vital vessels to the arm. In some cases a tunnel is cut through the solid bone, like a railway track through a granite mountain, to avoid exposure of the blood-vessels. Surely there is care and skill in such artifices.

78. *Protection against dislocation.*—The joints are supplied with what are called ligaments, principally designed to prevent dislocation. Ligament is one of the strongest tissues of the animal body. It is of various shapes and forms, fitted to the joint it has to protect. The ligaments serve as binders to tie and fasten the joints together.

But though the joints, by their structure and their ligamentary attachments, are provided with reasonable security against displacement, yet accidents of the kind, from various species of external violence, may often occur. And here we may remark, that perfect security against accidents is not consistent with the scheme of nature. Were it not for the accidents and uncertainties to which we are liable, many of the noble faculties of the mind would remain undeveloped. Take away from man the exertion necessary to procure himself means of sustenance, and to protect his health and his life, and you would leave him in danger of suffering irreparable injury, in his moral and intellectual constitution. Man, therefore, is sufficiently secured against accident to enable him to perform, with reasonable prudence, all the necessary exercises of the body. If he would imprudently, excessively, or dangerously use his limbs, he is deterred by the admonitions of pain; and, surely, the peculiar pain of a dislocated limb is sufficient caution, as the writer has ample means of knowing, having repeatedly suffered dislocation of the shoulder.

LECTURE IV.

STRUCTURE, RELATIONS, AND DESIGN OF THE MUSCLES OF ANIMALS.

Muscles—Structure of muscle—Contractibility—Contractibility a peculiar endowment—Great power of the muscles—First condition of muscular power—Second condition—Voluntary and involuntary muscles—Vital motions all involuntary—Involuntary muscles never get weary—Voluntary and involuntary muscles not equally affected by the same stimulus—Great number of the muscles—Relations between the muscles and the joints—Pairs of muscles—Use of tendons—Mechanical disadvantage of muscular action—Rapidity of muscular action—Pulley muscles—Slit tendons—Sphincter muscles—Of the muscular sense.

79. *Muscles*.—We have seen that one of the most important offices of the bones, is to serve as instruments of motion. But, bones are passive; they have no more power to move of themselves than a handspike or crowbar. To effect motion, they must be acted on by some force. The power operating in the animal system to produce motion is called muscular, and the part of the body possessing this power is called a muscle. I cannot, for my life, conceive why it should be called by this name. The word is Greek, and is derived from the word signifying a *mouse*; but what possible resemblance can be discovered between a muscle and a mouse, I have been unable to conceive. Probably some old Greek anatomist fancied he saw some resemblance.

If you remove from an animal the skin, and then all the fatty parts under the skin, there will be left what is usually called lean meat, which may be easily separated into portions of various shapes, detached by a very delicate kind of skin. These parts, into which the lean portions of the carcass may be divided, are muscles. They may be examined to advantage in a piece of beefsteak or in a ham. In your own body you may examine them and their action to best advantage in the calf of the leg, the body of the thigh,

between the shoulder and the elbow, and also between the elbow and the wrist. They are of various shapes—long, flat, and circular; but the best developed in form, the long ones, are larger in the middle than at the ends, being shaped something like a leech or an angle worm. The middle part is called the body. Of the ends, one is called the origin and the other the insertion. All the muscles of voluntary motion extend from one bone to another, over a point. For example, the muscle which raises the fore-arm by bending the elbow has its origin near the shoulder, its body just above the elbow, and its insertion below the elbow. The color of the muscles in most animals is red. This, however, is owing to the amount of blood which they retain, even after death. In birds and fishes the color is usually white.

80. *Structure of muscle.*—On examining muscle, as it is presented on your table in the form of beefsteak or ham, you will perceive it composed of fibres or strings. Scientific analysis reduces the fibres to still smaller strings, called filaments. These threads are so small that twenty thousand of them would scarcely make a bundle an inch in diameter. These minute threads are collected together in a kind of sheath, so as to form a fibre. Several fibres are again collected, so as to form a bundle, and several bundles form a muscle. Coarse muscle is made up of large bundles, and delicate muscle of small bundles.

81. *Contractibility.*—Muscles are endowed by almighty Power and infinite Wisdom with a vital principle, called contractibility. By this power the fibre suddenly shortens itself, so as to bring the two ends, and the bones to which those ends are attached, *nearer* to each other. It is by this means that motion is effected. Suppose you have a bow, such as you have seen Indians and children use. Its two ends are connected by a string. If you shorten the string, the ends must approach. Suppose, now, the bow, instead

of being one flexible, curved piece of wood, should consist of two straight pieces, connected by a spring joint, and suppose that the string should be endowed with the power of shortening and relaxing itself at pleasure. The contraction of the string would bend the joint, and bring the ends of the bow together. The relaxing of the string would suffer the spring joint to straighten the bow. Such is an illustration of the action of the muscle in producing motion, only instead of a spring joint there is an antagonist muscle, on the other side, to straighten the limb. Let us apply this illustration to the bending of the arm at the elbow. Suffer your arm to lie, in its natural position, extended at your side. It resembles now a *straight* bow. One end of the muscle or string is fastened to the upper bone of the arm near the shoulder—the other end to the lower part of the arm, toward the wrist. When the muscle contracts the body swells, and the two ends approaching bend the elbow joint, and thus raise the hand. You may easily perceive the swelling of the muscle consequent on contraction, by placing the palm of your hand on the body of the muscle, just above the elbow, and then raising your arm.

82. *Contractibility a peculiar endowment.*—The contractile power of muscles is a special endowment for a special purpose. No other part or tissue of the body possesses it, nor is the muscle dependent for its power on the nerves or any other organs. It is true that stimulus of some kind is necessary to cause it to exert its power, or it might lie dormant. But neither nervous influence, nor any other stimulus, can communicate to muscle its power of contraction. The almighty One, in the plenitude of his wisdom, gave this special property to these organs, and to no others. The muscle is the source, not the application of power.

83. *Great power of the muscles.*—The force of muscular action is sometimes surpassingly great. Under the ordinary circumstances of human life, the full power of the muscle is

seldom used. The amount of energy which the muscles may put forth, seems to depend on two conditions.

84. *First condition of muscular power.*—The first condition of muscular energy, is the health and full development of the part. A large, plump, full, healthy muscle, is vastly stronger than a small, sickly one. Health and large size depend wholly on the amount of nutriment received. The amount of nutriment received by any part depends on the quantity of blood sent to it, and the quantity of blood depends greatly on the exercise to which the muscle is subjected. Hence we see the reason of the vast strength exhibited by some persons. It is the result of exercise and long practice. Dr. Brewster tells of a man who could lift eight hundred pounds with his hands, and could hold nearly a hundred pounds by his teeth.

Indeed, the connection between exercise and strength is so obvious, as scarcely to need a single remark. God has, in his wisdom, established this connection, thereby promoting man's physical, moral, and intellectual improvement.

85. *Second condition of muscular power.*—The second condition of muscular energy is the amount of excitement transmitted to it through the nervous system. A man, under the influence of violent passion, or of sudden alarm, will accomplish a feat altogether beyond his power in his cooler moments. Insane persons sometimes exhibit amazing strength. Convulsive motions in disease are sometimes inconceivably powerful. The English writers tell of a slender girl, affected with convulsive action of the muscles of the back, so as to throw the body into an arch, resting on the heels and the head, who raised a weight of nine hundred pounds, laid on the abdomen with the intention of keeping the body straight. In such cases the muscles acquire no additional strength; they only are more highly stimulated to exert their inherent or acquired power.

86. *Voluntary and involuntary muscles.*—There is a

great difference in the power of our will over the motions of different classes of muscles. The muscles of the arm, of the leg, and, in general, all the muscles of motion, are completely under the control of the will. We may move or not, as we please. But the muscles of the heart, and the stomach, and the intestines, are in no way subject to our control. We cannot make the heart beat, nor can we stop it. We cannot, by our will, increase nor diminish the movement of the stomach, nor the peristaltic motion of the intestines. The muscles of respiration we can, in fact, control; we can suspend for a time their action; yet, if let alone, they will go on without any care of ours.

These facts have led to a classification of muscles into voluntary and involuntary.

87. *Vital motions all involuntary.*—The involuntary muscles are those, without whose action life, even for a short time, could not be maintained, they being muscles of respiration, of circulation, of digestion, and of nutrition. These operations must continually go on, or the wheels of life would stand still.

We see the wisdom of the Creator in making these motions involuntary. Had man to direct his own operations of breathing, and of circulation, and of digestion, he would have no time to attend to any thing else. He could not go to sleep, he could not labor, nor talk, nor read, nor think, but must be wholly engrossed in the care of those vital operations. Should he falter, or slumber, or be inattentive even for a moment, he would be a dead man. God, therefore, has wisely and mercifully placed all the motions necessary for the continuance of organic life beyond man's care or control.

88. *Involuntary muscles never get weary.*—All the voluntary muscles are susceptible of weariness and fatigue. A long walk wearies you. Continued motion of the arm, in any one direction, becomes painful. You cannot even stand

long in the same position without fatigue. Even the muscles of the tongue—and of woman's tongue, too—get weary. But the muscles of organic life, of vital motions, know neither rest nor fatigue. They go on, on, on, for ever, till life itself ceases. You breathe night and day, but never get tired of breathing. The action of the stomach and bowels is incessant, yet never fatiguing. And there is the heart; it never sleeps, never rests, never falters. On, on it goes—pump, pump, pump, at the rate of sixty strokes a minute, four thousand an hour, and a hundred thousand a day, for a hundred years together, without disorder and without weariness. On it goes, yet never seems exhausted, never fatigued. On it goes, while we stand and while we sit, while we wake and while we sleep, while we are sick and while we are well.

How came these two classes of muscles to differ so widely? No microscope can discover the slightest difference between the muscular fibres of the heart and of the hand. Their mode of action is precisely the same, being alternate contraction and relaxation. Why, then, should the one be often fatigued, the other never—the one demand frequent rest, the other perform incessant motion? Surely herein is unfathomable wisdom and unquestionable benevolence.

89. *Voluntary and involuntary muscles not equally influenced by the same stimulus.*—The voluntary muscles, as we have seen, are under the influence of the will, and the nerves form a connecting medium between the will and the muscle. But voluntary muscles are but slightly influenced by external bodies. Touch a voluntary muscle, and only a very few fibres will contract, while the greater portion of the muscle remains unaffected. On the other hand, touch an involuntary muscle, and the whole is thrown into action. If you touch a portion of the stomach or the intestines with any substance, the whole organ is thrown into successive

contractions and relaxations. Yet, these same involuntary organs are scarcely affected by nervous irritation, such as would throw the voluntary muscles into convulsions. We see here another evidence of Divine wisdom. The voluntary muscles being agents of the will, are excited through the nerves. The involuntary, being in no sense agents of the will, are but slightly affected by nervous irritation, while they are exquisitely sensible to the presence of foreign substances. Now, it should be remembered that the business of these involuntary muscles is to operate on foreign substances. The heart has charge of the blood, the lungs of the air, and the digestive muscles of the food. They, therefore, should be susceptible of stimulus from the presence of those bodies on which their action is to be exerted. The business of the digestive organs is to act on food. They are, therefore, stimulated by any foreign substance, be it food or poison, or even a knife. The voluntary muscles can do nothing with such substances; therefore, their presence affords no stimulus to action.

Here we see the design and the wisdom displayed, in giving such different properties to the same animal structure.

90. *Great number of muscles.*—There are several hundred muscles in the human system. It is difficult to determine the precise number, from the fact that the natural limits of the muscles are not always well marked, and that the grounds of demarkation between different muscles have not yet been by anatomists well established. The lowest estimate is four hundred. Yet, for all there are so many, they seldom, if ever, interfere with each other's action. Many motions of the body are effected by the combined action of several muscles, under the principles of the composition of forces in mechanics.

Let, now, any mechanic, even a sailor, undertake to construct or navigate a machine with four hundred ropes, acting on levers and over pulleys, and he would find it no small

matter to get the hang of "every rope in the ship." Yet, here is a ship, with four hundred ropes, of every possible variety of length, and shape, and direction, and complication, navigating securely the stormy sea of life.

91. *Relations between the muscles and joints.*—The bones being levers, or instruments of power, the joints being the fulcrum or prop of the lever, and the muscle being the power, we see wisdom exhibited in the local relations between these parts. Four hundred muscles might be susceptible of an untold number of permutations, arrangements, and combinations. But the anatomist will tell you, that of all the conceivable arrangements none would be so judicious as those adopted by nature. In no case is a motive muscle placed where there is no joint. In none is there a joint where there is no muscle. In none is there a failure in adaptation of the muscle to the joint. A hinge joint is always furnished with muscles to give the limb the swinging motion which that species of joint admits. A rotary joint is always supplied with sets and combinations of muscle to produce rotary motion.

Had chance had the disposition of the muscles and joints, what would have hindered the throwing of the joint entirely out of reach of its motive power? But infinite Wisdom has disposed all, so that nothing is wanting—nothing superfluous. All is adjusted, all related, so as to produce wise and benevolent results. The wisdom of these relations will still more clearly appear, when we consider that the disposition at the joints of any other animal tissue than the muscular, would have been useless for the purposes of motion. Cellular, adipose, or nervous tissue, molded into the very form of muscle, would be ineffective for the want of contractile power. Therefore, the relation is threefold—a relation of constitutional endowment, of form, and of direction.

92. *Pairs of muscles.*—The muscles generally act in

pairs, antagonistic to each other. One draws the limb forward, the other back. There is one to thrust the foot forward, another to throw it back. One bends the finger, another straightens it. Paley compares their relative action to the movements of two men with a cross-cut saw. But there is this difference: neither of the antagonist muscles ever, like each sawyer in turn, entirely relaxes. It always holds on with more or less force. Some parts of the body are retained in shape by the mutual action of antagonist muscles. If one of the pair loses its power, the other draws the part out of its natural position. Should the muscle on one side of the face be paralyzed, the one on the other side would draw the mouth awry—a sad deformity. Sever the muscle on one side of the neck, and that on the other would twist the head around.

93. *Use of tendons.*—It very often happens in the animal frame, as in other machines, that the presence of the motive power at the point where its action is wanted would be inconvenient. The usual expedient adopted in machinery for transferring the effects of the power to a distant point, is the employment of a rope or strap. Such is precisely the office of the tendons, or cords, which are long straps, attached at one end to the muscle, and at the other to the bone, or part intended to be moved. If the hand had been encumbered with all the muscles necessary for the movements of the fingers, it must have been greatly shorn of its beauty, and of its office as a delicate mechanical instrument. The muscles, therefore, are placed high up on the arm, and their tendons pass along the wrist to the joints of the fingers which are to be moved. In the same manner the muscles which move the toes are disposed in the calf of the leg. By this wise arrangement both convenience and beauty are attained.

94. *Mechanical disadvantage of muscular action, and how compensated.*—By the general disposition of muscular power

there is what is called in mechanical philosophy a disadvantage. The bones are levers, the joints fulcrums, and the muscles power. Now there are three kinds of levers. In the first the weight is at one end, the power at the other, and the fulcrum between. This is the kind of lever used in prying a stone out of the ground with a crow-bar. By this method a very great weight may be raised by a very feeble power, provided you have a long lever and the weight and fulcrum near together. In the second kind the fulcrum is at one end, the power at the other, and the weight between. This is used in rolling up logs with a handspike. In this kind of lever you lose in power, but gain in rapidity of motion. In the third kind the fulcrum is at one end, the weight at the other, and the power between. The principle of this lever is applied in raising a ladder by placing one end against the foot of a wall, and raising the other over your head. In this way much power is sacrificed, but great velocity may be gained. Though all three kinds of lever are used in the human body, yet the third is most frequently adopted. A fine example of it may be seen in the motion of the fore-arm. Here the fulcrum is the elbow joint, the power acts at the insertion of the muscle just below the elbow, and the weight is the hand with whatever it may contain. But this is the very arrangement needed for rapid motions; and rapid motions are the most needed in the ordinary exigencies of human life. A man would not like, for the sake of being able to lift a thousand pounds in his hand, to be compelled to employ half an hour in raising his hand to his mouth. It would take one a long time to shingle a house if he had to press every nail down by the slow operation of the screw. How much better, by a slight, graceful, rapid effort, to drive the nail to its place at once! We owe all the graceful motions, delicate operations, and ingenious feats of human mechanism to this very arrangement of the motive powers. This very disadvantage,

therefore, as it at first seemed, proves to be a wise contrivance, by which even more is gained in velocity than is lost in power. It may also be remarked, that so enormously great is the power of muscular contraction, as we have seen in sections 84 and 85, that we can afford to sacrifice a portion of power in order to obtain variety and rapidity of motion.

95. *Rapidity of muscular action.*—There are many common and familiar acts of life, in which great velocity of motion, with incessant change of direction, is required. Look at the operation of writing. How rapidly is it performed! Yet not only every word, and every syllable, but every letter, and every element of the letter, requires a change of muscular contraction. How rapidly the musician touches the keys of the organ! How rapid the action of the muscles of enunciation! Man can distinctly articulate more than a thousand letters in a minute. And yet every successive letter requires both the contraction and relaxation of a new set of muscles.

96. *The pulley muscles.*—The pulley is a very simple, yet ingenious mechanical contrivance. Its design is to make a body move in one direction, while we pull in the opposite. By this means we may, while standing on the ground, raise weights to a great height. Cast a rope over a beam. To one end of the rope attach a weight, and pull away at the other end. You will thus, by pulling down, draw the weight up. This contrivance is called a pulley. It is employed in several parts of the muscular system.

The most curious and beautiful example of a pulley muscle is at the eye. It may be difficult to make this intelligible without a diagram, but I will try. The eye is a spherical body, placed in a cavity called the orbit, being a bony socket hollowed out on the front part of the skull. On the back side of the socket, next the brain, is a little opening giving passage to the optic nerve, which connects the eye with the brain. Just on the upper margin of this

aperture, the pulley muscle takes its origin. Thence it runs forward above the ball of the eye, inclining a little toward the nose, until it reaches the upper edge of the socket, under the eyebrow, where it passes through a cartilaginous ring fastened to the bone of the eyebrow. It then turns back and runs a little downward and outward laterally until it reaches the eyeball on the upper and outer side. Here it is inserted. By this marvelous contrivance an extensive series of motions, which could not by any other conceivable means have been obtained, is secured to the eye. By this means we can draw the eye forward, and look downward, without bending the neck. Consider, therefore, of how much importance this muscle is in reading and writing. Had we, in reading and writing, to keep the head all the time leaning forward, we should soon get weary. In addition to the downward movement, this muscle also affords a lateral motion toward the nose, and thereby enables us to direct both eyes to the same point.

There is, also, a species of pulley used in opening the mouth. The most obvious method of pulling down the lower jaw, so as to open the mouth, would be the attachment of a muscle to the breast to run direct to the tip of the chin. The direct action of such a muscle would draw the jaw down. But, then, a muscle running in a straight line from the breast to the chin would spoil the beauty of the neck, and might interfere with the easy motions of the head. Therefore, to accomplish this important purpose, the opening of the mouth—and surely few purposes in the animal economy are more important—a muscle is provided, taking its origin in the temporal bone, just behind the ear, thence running downward and forward till it reaches a point in the neck lower than the tip of the chin. Here it passes through a loop or ring formed on purpose for it in another muscle. Thence it runs on and is inserted into the chin. By this remarkable contrivance the contraction of the mus-

cle, which otherwise would have pulled the jaw up, and thus closed the mouth, now pulls it down.

A modification of the pulley occurs in the foot. The muscles which bend the toes upward are attached at their origin to the bones of the leg. If they ran direct to the toes, they would form a queer-shaped ankle, which would be a caution to boot-makers. To avoid this inconvenience the muscles run down the leg to the instep, where they are bound down by a ligamentous clasp. Passing out from under the clasp, the tendons run along the foot to the toes. Were it not for this clasp every motion of the foot would throw the ankle into a shape resembling the space between the toes of a goose.

97. *Slit tendons*.—If two ropes running along side by side, from points adjacent each other, should have their movable ends inserted at different points in the same line, the one inserted at the most distant point must necessarily, in running by the other, cause a rubbing and interference at the point of transition. The only obvious means of avoiding friction would seem to be the division of the shortest rope into two strands, near the point of its insertion, in order that the other might pass between the strands to its destination. Precisely such a contrivance is found in the tendons which move the fingers. The muscles of the fingers all have their origin in the same neighborhood on the arm. Their tendons run along nearly parallel. One tendon must be inserted into the first bone of the finger, nearest the palm of the hand. The second tendon must run by to the second bone, and the third to the last bone. To avoid the wear and tear of rubbing, the tendon, for example, which moves the second joint, and which we will call the second tendon, runs along parallel to the third tendon, but on the upper side of it. Just below the joint of the second bone the second tendon is slit, or bifurcated, like the prongs of a fork, permitting the third tendon to pass

through, and go on unimpeded to its point of insertion in the end of the finger. By no other known method could the free and easy motion of these parts be secured.

98. *Sphincter muscles*.—A most curious form of muscle is that called the sphincter, from a Greek word, signifying to constrict or bind tight. This form of muscle is used in closing the apertures of the body. Its action resembles that of a string surrounding the mouth of a purse.

The most beautiful specimen of the sphincter muscle is found in the eye. It surrounds the opening in the eye called the pupil, or sight. In man it is a perfect ring, and, under all circumstances, retains its shape. There are, in fact, two circular muscles around the pupil of the eye—one exterior, the other interior. The exterior is called the radiated muscle, because its fibres proceed like rays, or spokes of a wheel, from the margin of the pupil to the outer circumference of the iris. Its use is to dilate the pupil so as to let in more light. The interior muscle is formed of concentric circles, like a series of elastic hoops, one inclosed within the other, in the form called a nest. Its use is to contract the pupil so as to shut out light when too much falls on the eye.

You may easily see the effect of the action of these muscles in the eye of another, or of yourself. Bring a candle suddenly near the eye, and the interior muscle contracts, and, by diminishing the diameter of the circles or hoops, renders the pupil smaller, and shuts out the excess of light. Remove the light, and the exterior muscle contracting, from its radiated structure, enlarges the pupil. By the aid of a looking-glass, you may see the operation in your own eye. Turn toward a window, and the pupil is contracted. Turn toward some dark corner of the room, and it dilates.

Now, let it be observed, the presence of light seems not to stimulate the exterior muscle at all, but to produce sudden contraction of the interior, while the removal of the

light leaves the interior to resume its natural position, but stimulates the exterior to sudden contraction. Also, by the use of muscles differently constituted, the same power of contraction produces opposite results. The contraction of a circular sphincter muscle produces diminution of the pupil, but the contraction of a radiated sphincter muscle produces enlargement of the pupil.

If this constitution of the muscles of the iris of the eye does not display design, contrivance, skill, and wisdom, I know not in what department of science or art to look for any evidence of intellect. Look merely at the shape of the pupil. It is always changing its size, yet always retaining its perfectly-circular shape. Let, now, any mechanic or geometrician try to make a circle always changing its diameter, yet always remaining a perfect circle, and I know not what materials he could use, or how he could so dispose his threads as to produce so curious a result.

99. *Of the muscular sense.*—We have seen (§81) that the muscles are endowed with a living principle called contractility, thereby being distinguished from every other tissue of the body. Sir Charles Bell maintains that the muscular system is the seat of a peculiar sense, bearing the same relation to its appropriate impressions that sight bears to impressions of light, hearing to sound, smell to odors, taste to food, and touch to external bodies. He calls it the sixth sense, and gives it the name of muscular sense. I have not had access to Sir Charles Bell's Lectures on Anatomy, in which this curious matter is discussed, but there is a brief explanation of his views in his Bridgewater Treatise, and there is also a discussion of the subject in Brown's Philosophy of the Mind. To this muscular sense he refers the feelings of the infant, when in danger of falling—feelings often exhibited in children before they have learned the effects of falling—the knowledge of the position of our limbs, and of the exertion used in overcoming resistance—

the painful sensations apparently felt in an amputated limb—sensations the same as if the limb were hanging by the side, or lying across the breast. To this sense, also, are referred the pleasures of exercise in young animals, and all the feelings of weariness, fatigue, sickness, and lassitude. If such be the fact—if the muscular system be really endowed with a distinct sense—it adds to the importance of the muscular tissue in the animal economy, and explains the reason why motion and exercise are such fruitful sources of exquisite pleasure to animals.

LECTURE V.

THE NERVOUS SYSTEM.

Nerves—The Brain—Structure of the nerves—Classification of the nerves—Nerves of organic life—Sensation and motion not indispensable to life—Nerves of special sense—Nerves of common sensation and of voluntary motion—Power and wisdom exhibited in the organization of the nervous system.

100. *Nerves.*—We have seen that the bones are mechanical levers, or instruments of motion, and that the muscles are the motive powers. Another class of organs is still necessary. The muscles, though they are endowed with life, and with a special property called contraction, by means of which they have power, yet they have no intelligence. They are not the mind, nor can the mind influence them directly. Cases often occur in which a man has no feeling whatever in his limbs, and no more power over them than over a block of wood or a stone. There is, therefore, some connection needed between the mind and the muscular system—some system of organs to serve as instruments of the mind to act on the muscles. This is furnished in what is called the nervous system.

101. *The brain.*—We have already frequently referred to the brain, and to the great care taken for its protection. The universal sentiment of mankind, sustained by facts, is that the brain is the organ of the mind—that through the brain the mind acts on the rest of the system. But how it acts no man can tell; all is involved in mystery; the fact only is known. The philosophy or reason of the fact is unknown. The brain is inclosed in the cavity of the skull. The substance of the brain seems precisely similar to that of the nerves. There are in the skull bone several openings to permit nerves to proceed from the brain to the eyes, ears, nose, and mouth. Also, there is an opening in the bottom of the skull to give passage to the spinal marrow, which

may be considered one great nerve. There are, also, openings from the spine all the way down, (§52,) to give passage to branches of the spinal marrow, in the shape of small nerves, to every part of the body. The nervous system, therefore, comprehends the brain, spinal marrow, and nerves, all consisting of the same elementary matter, having the same structure, and forming one grand system, all connected together. The brain seems to be merely the centre of the nervous system.

102. *Structure of the nerves.*—What is called by anatomists the nervous tissue, whether taken from the brain, spinal marrow, or nerves, appears to the eye of a soft, pulpy consistence. In infants it is nearly fluid; but in mature life it acquires more firmness, and should be classed as a solid. When analyzed, or reduced to its elements, it seems composed principally of water, albumen, phosphorus, sulphur, potash, and lime. There is surely no reason, except the wisdom of the supreme Being, why these elements, organized in nervous tissue, should possess such wonderful endowments, whereas the same ingredients, organized in other animal tissues, should possess altogether different properties. What is properly called a nerve appears to the eye like a white cord or tendon. They were, indeed, mistaken for cords or tendons by the early anatomists. They are now called nerves, from a Greek word signifying a string. When a nerve is cut, there will appear within several little strings. They may be drawn out and examined separately. On examining carefully with the microscope, it appears that every nerve consists of a sheath inclosing several little cords. Every little cord, also, is found to consist of a sheath inclosing several very small nervous filaments. These nervous filaments resemble, in appearance, fibres of raw silk. They are exceedingly minute; every one of them extends continuously, without interruption, the entire length of the nerve. Every filament,

therefore, seems to resemble a galvanic wire, reaching from the brain to the extremity of the nerve. Several of these filaments, collected in a common sheath, form a nervous fibre, or small cord; several fibres, collected in a larger sheath, form a nerve. Thus the nervous matter is protected, first by a common sheath inclosing fibres, and secondly, by another sheath inclosing filaments. Some anatomists say, further, that each filament is a tube inclosing a thread of soft, semi-transparent matter.

The chemical and mechanical structure of all the nerves is perfectly homogeneous or similar. How, then, came they to possess, as we shall see, properties so greatly differing?

103. *Classification of the nerves.*—No two anatomists or physiologists, to whose works I have had access, agree in classifying the nerves. Cruveilhier, one of the latest anatomical writers, makes no distinction whatever. He considers the different properties attributed to the nerves, as belonging to the organs to which they are distributed; that nerves are only conductors, like galvanic wires; that they are conductors of sensation when they are distributed to a sensory organ, and of motor influence when distributed to a motor organ. On the other hand, Sir Charles Bell, so far as I can gather his views from indirect sources—for I have never seen his work on the subject—considers each filament of nerve as endowed with a distinct and single property; that one filament, for example, is endowed with the power of exciting involuntary motion; that another excites voluntary motion, but conveys no sensation; and that a third conveys impressions of sensation, but has nothing to do with motion. On the whole, it seems to me that the subject will be most easily rendered intelligible, by considering the nerves in four classes: (1.) Nerves of organic life; (2.) Nerves of special sense; (3.) Nerves of common sensation; and, (4.) Nerves of voluntary motion.

104. *Nerves of organic life.*—There is a system of nerves,

usually called by physicians the great sympathetic nerve. It consists of a series of nervous knots, called ganglions, joined to each other by a nervous trunk, and extending along down the side of the spine, from the base of the skull to the lowest bone of the spine. This system of nerves does not seem to originate directly from the brain, but it is connected, by innumerable nervous filaments, with every part of the brain and of the spinal marrow. It sends out branches of nerves to all the involuntary organs of the body, especially to the organs of digestion. Wherever in the human system is found an organ of vital duty, independent of our will, there will be found a branch or filament of this system of nerves. Its presence seems essential to the operations of life. Man might live, at least for a time, were all the other nerves paralyzed. But, paralyze this, and the organs of circulation, of digestion, and of nutrition, would immediately cease to perform their office, and man could no longer exist as an organized being; his organic structure would at once become dead matter, and the process of dissolution and of decomposition would immediately commence. Hence, this system of nerves is properly called nerves of organic life.

This system is also called the great sympathetic nerve, because it unites all the vital organs of the frame together, and connects them with the spinal cord and the brain. So close is the union, that if one part suffers the others suffer also, as if by sympathy. Hence, the epithet sympathetic seems appropriate. This system of nerves forms no medium of connection between the will and the organs to which the branches of nerve are distributed. Hence, all the organs supplied by it are beyond the control of our own volitions. We have seen (§87) how important to us is this constitution of our bodies.

These nerves seem not to be conductors of sensation. They may be cut and torn without causing any pain. We

never, therefore, receive through them sensations of pain in the internal organs of the system. Their only office is to preside over the involuntary operations of organic life. We, however, do receive sensations of pain in the heart, and stomach, and bowels, and other of the involuntary organs. This fact is easily explained, on the supposition, that inasmuch as the nerves of motion and sensation communicate directly with the sympathetic system, along the spinal column, sensitive and motor filaments may be sent from these sources, and distributed with the filaments of the sympathetic.

105. *Sensation and motion not indispensable to life.*—It is evident a man might be unable to see, or hear, or feel, or move, and yet be alive. The heart might still beat, the lungs might still act, digestion might still go on; and, so long as these vital operations should continue, life might be sustained. Even respiration might become so feeble as to be imperceptible. If at the same time the heart should diminish its action in proportion to the diminished breathing, the man might still live. The action of the heart and of the lungs are often nearly suspended, or rendered so feeble as to be imperceptible, in fits of fainting. Suppose, now, by disease or accident, the nerves of sensation and of motion should become paralyzed, and at the same time respiration and the circulation be suspended. The man might seem to be dead, and yet, should the nerves of organic life still retain their efficiency, all the vital functions might still be performed, and the man live for some days.

Is there not reason to believe that death is often only apparent? May not the nerves of sensation and motion be paralyzed, by accident or disease, and the nerves of organic life still perform their office? Have we not cause to fear, that sometimes, in our hurried burials, we consign to the deep, damp, dark dungeon of the grave those from whom the spirit is not yet departed? May not the buried child, buried

too hastily, wake up in the grave, dreaming that it is lying in its own bed, and call for its mother? There is only one sure sign of death—that is decomposition. So long as organic life remains, the system resists the laws of decomposition. So long, too, the spirit remains. But when once organic life ceases, decomposition commences, and the spirit at once departs. Be not, therefore, in too much haste to “bury your dead out of your sight.” Whatever may be the custom of society, wait until you see unmistakable signs of putrefaction. When once that commences you may know that all is over, and that earth claims its own. You may then commit dust to dust, with the assurance that your friend will wake no more, till the morning of the resurrection.

106. *Nerves of special sense.*—By this we mean the nerves of seeing, hearing, smelling, and tasting. They proceed directly from the brain, through openings in the skull. These are called nerves of special sense, because each one is endowed with power to conduct impressions only of a special kind. Thus the auditory nerve, or nerve of hearing, can convey no sensations except those of sound. It is not capable of conducting impressions of sight, nor of feeling. It may be pricked, cut, and torn, without any consciousness of pain. It is also wholly independent of the will, and hence we cannot use it as a nerve of motion. So, also, the optic nerve is totally insensible to all impressions except those of light. It cannot feel. You may gash it all to pieces, and no pain would be felt. It is not capable of transmitting sensations of sound, nor taste, nor smell, nor volitions of the soul.

107. *Nerves of common sensation and of voluntary motion.*—It has long been known that if the nerve proceeding from the spinal cord to any particular limb be cut or tied, the power to move that limb at will, or to feel any sensation in it, is lost. For a long time it was supposed, therefore, that one and the same nervous filament was capable of

performing two separate and distinct offices—of conveying the decisions of the mind from the brain to the limb, and of conducting impressions or sensation from the limb back to the brain. But Sir Charles Bell, to whom we have often referred, discovered that each nerve, supposed before his time to be a nerve both of sensation and of voluntary motion, had two roots at the spine. These two roots after proceeding a short distance from the spinal cord unite in one trunk, and proceed along, bound up in the same sheath. If the nerve be cut below the point of union, both sensation and motion are destroyed. Also, if both roots above the junction be cut, both sensation and motion are equally destroyed. But if one of the roots only be cut, and the other remain uninjured, sensation only is destroyed, and motion remains. But if that other be cut, and the first be unimpaired, motion is lost, while sensation remains. We are, therefore, led to the conclusion, that the nerve, for example, which goes to the arm, has two sets of small fibres bound up in the same sheath; that one is used by the mind to stimulate the muscles of the arm to perform such acts of power as we desire, but cannot be used to conduct sensations of heat or cold, or pain, from the arm to the mind. The other set is, in like manner, used to convey sensations; but cannot transmit nor produce voluntary motions. We may, therefore, lose our power of motion, and still retain feeling; or we may lose feeling, and still retain voluntary motion; or we may lose both. Paralysis of one and the same species of root in all these nerves would destroy either motion or sensation, as the case might be. Paralysis of both roots in all, would leave us without the power of moving or feeling; but still we might live, so long as the organic or sympathetic nerves were unimpaired. Paralysis of the organic also, would destroy not only motion and sensation, but every vestige and sign of life.

108. *Power and wisdom in the organization of the nervous*

system.—We have seen (§102) that no physical reason can be given why the nervous substance should have properties so peculiar, and so distinct from other substances of the body. We have seen, also, in the same section, that no chemical analysis nor microscopic glass can detect any difference in nervous matter. Why, then, should one set of nervous fibres be instruments of motion only, and another set of fibres, in no way distinguishable in substance or appearance from the former, be an instrument of sensation only? One set of fibres conveys impressions of sound; one of sight; one of taste; one of smell; one of touch—one is an instrument of voluntary movement, and another stimulates the vital organs to their incessant task.

None ever mistakes its duty. The optic nerve is never caught smelling, nor the olfactory hearing. Nerves of motion are never interfering with those of sensation.

Each organ, each tissue, each part of the human system has, in the order of infinite Wisdom, its appropriate endowment—its allotted part—its prescribed duty. Each knows its place, and keeps it. Each understands its own business, and minds it. There is no lording it over one another—no intermeddling, officiously, with each other's work. There is a wise division of labor among the several organs, and each is perfectly content with its allotment.

Human society might, surely, learn a lesson from the animal economy; and many a busy-body might receive a wholesome reproof from his own physical constitution.

LECTURE VI.

THE DIGESTIVE APPARATUS, AND PROOFS OF DESIGN THEREFROM.

Digestion—Necessity thereof—Instruments for obtaining food—The mouth—The teeth—Composition thereof—Number and classification—Modifications in different animals—Relation between the teeth and food of infancy and of age—Teeth formed prospectively—Renewal of the teeth—Saliva—The pleasure of taste—Passage of the food to the stomach—Swallowing an involuntary operation—The stomach—Change of food therein—How produced—The gastric juice—Its solvent power—It has no power over living matter—It is formed as it is needed—Hunger a special endowment—Motion of the stomach during digestion—Changes of food in the intestines—Course of the chyle—Indications of design—Structure and design of the lymphatic vessels—Complication of the digestive apparatus.

109. *Digestion.*—We have seen (§23) that organic bodies grow by incorporating with themselves the materials furnished from the inorganic creation. We have seen, further, (§30,) that animals have a peculiar apparatus for preparing, modifying, and assimilating to themselves the matter furnished by food. The process by which the food is converted into living, animal matter, is called digestion, from a Latin word to divide, distribute, and arrange. The process of digestion is very curious and complicated, and the apparatus by which the work is performed very wonderful.

110. *Necessity of the process.*—The necessity of a constant supply of food, and of an uninterrupted process of digestion, arises from three conditions of animal organization: (1.) The condition of development. Man is born into life a mere, puny infant. He has but a small body, and many of his organs are yet imperfect. The development of his organs, and the general growth of the body, require the continual addition of new particles from foreign sources. Organic increase consists not in the expansion of a texture previously condensed, like filling a flaccid bladder with

wind, but the new material added must be incorporated with those previously existing, and become identified with the living substance.

(2.) The living structure is liable to occasional injuries from wounds and disease, thereby requiring frequent repair. Materials for repair should be constantly on hand, and the tools all ready to work them up. Indeed, the gate should be always hoisted, the wheels all in order, the bands all adjusted, and the whole machinery in motion, or irreparable injury might be suffered by the delay necessary in getting the mill in grinding order.

(3.) We have seen (§19) that constant and progressive change seems to be one of the characteristics of life. Hard and unyielding substances answer not the purposes of organization. Human machines endure in proportion to the hardness and durability of the materials composing them. But in organic structures this very condition hastens dissolution; for when, in age, the tissues become hardened, death results from that very cause. Were we to plan an edifice for durability, we should not select perishable materials, such as "wood, and hay, and stubble," but "silver, and gold, and precious stones." We should hew from the quarry the solid marble, or the more solid granite, and dig from the mine the enduring iron and imperishable brass. But such materials will not do for the mansion of the soul. She at once and for ever abandons such a residence. Her house must be built by Divine hands, of plastic materials, capable of continual alterations, displacements, and adjustments—varying perpetually both in kind and degree, according to the progressive stages of their internal development, and to the different circumstances which may arise in their external condition. We have seen (§19) how great and rapid are the changes to which the living being is, from its very nature, subjected. Hence we see the necessity of a special system

of organs, in constant action, to carry on the work of removal and replacement—of modification, and alteration, and renewal.

111. *Instruments for obtaining food.*—Every animal is endowed with external organs convenient for the purpose of procuring food. In man the hands are designed to bring the food to the mouth. Man's mouth is not fitted for grasping the food, like the ox, or seizing it, like the cat, or lapping it, like the dog. His hands are designed to place it at the mouth.

112. *The mouth.*—As every one knows very well the way from the hand to the mouth, and finds little difficulty in getting food into the mouth, when he once has it to put there, we will examine the mouth only so far as it is designed to act on the food. The lips are designed for gates, to open when the food enters, and then to close the cavity of the mouth, in order that the food, especially liquids, may be retained. But they answer a still more important purpose. There is constantly forming in the mouth a liquid, called saliva. This substance is of great use in digestion; were it not for the lips, it would constantly be trickling from the mouth, thereby causing great inconvenience externally, and much loss to the internal operations.

The tongue receives the food from the lips, passes it over to the teeth for mastication, receives it from them again, rolls it into a ball, and assists in swallowing it. The tongue is also the principal organ of taste. From its position, size, shape, and structure, it is peculiarly adapted to all these purposes. Of its use in articulate language we speak not now. We merely remark, that the disposition of the tongue at a point of the human frame where it might, at the same time, answer purposes so different as eating and speaking, is a mark of design and wisdom.

113. *The teeth.*—The most of the changes of the food, in the process of digestion, are effected by the action of

fluids formed for that purpose by appropriate organs in the stomach and intestines. These fluids can act on the surfaces of food. Solid lumps would be very difficult of digestion, and would require a long time. The work could only be effected by exposing to the action of the gastric fluid successive surfaces, which, in turn, dropping off, would leave a new surface beneath, until the lump might be finally reduced. The process of digestion, therefore, is greatly facilitated by reducing the large lumps of food to as small particles as possible, before it enters the stomach. To accomplish this important purpose, the teeth are wisely placed on the direct road to the stomach.

114. *Composition of teeth.*—The teeth are formed of the same material as bone, but are much harder, owing to the greater proportion of phosphate of lime used in their composition. The hardness is necessary to adapt them to grinding hard substances. The external surface of the teeth is covered by a layer of very hard, smooth substance, called enamel. It is much harder than bone, and is principally designed to prevent the teeth from wearing out, in their exposed condition, and in the discharge of their laborious duties.

There is a remarkable peculiarity in the structure of the teeth of the gnawing animals, such as the beaver. The design is to keep their front teeth constantly sharp, like an ax. To accomplish this, the tooth is furnished with a layer of enamel only on the front surface. The back part of the tooth, composed only of common ivory, is constantly wearing away, so as to preserve the tooth of a wedge-like form. Had it not been for this contrivance, the tooth, from frequent use in gnawing, must soon become blunt, and unfit to perform its office.

115. *Number and classification of the teeth.*—There are in the human system precisely thirty-two teeth; never more, unless some old tooth is suffered to remain on shedding; nor less, unless some one or more be lost by disease or accident.

They are of three distinct classes: (1.) The cutting teeth. These are eight—four in each jaw. At their extremities they are sharp like an edged tool, and are designed for biting off and cutting the food. (2.) The canine, or dog teeth. These are four—two in each jaw. They come to a point, and are designed to tear the food. (3.) The molar, or grinding teeth. These are twenty—ten in each jaw. They are designed to grind up the food.

116. *Modifications of teeth in different animals.*—There are variations in the class of teeth furnished different species of animals corresponding to the different kinds of food used by them. Animals living on herbs, such as the cow and sheep, have no canine teeth, but are furnished with powerful grinders. Carnivorous animals, such as the lion and wolf, have powerful canine teeth, to tear the flesh that forms their food. Man has all three sets fully developed, fitting him for living on varieties of food. Lobsters have teeth in their stomachs. Birds have no teeth at all, but, instead thereof, a gizzard, adapted to grinding grain, like two millstones, while the crop serves for a hopper. This is a very convenient arrangement for fowls. They can fill up their crop with corn and go to roost. While they sleep, the grinding goes on, kernel after kernel passing into the gizzard, till all is ground, and then the mill stops of itself. As they cannot take out the gizzard to pick it as the miller does his millstones, Nature has taught them to swallow gravel, which answers the same purpose.

So perfectly adapted are the teeth of animals to their food, that a naturalist may, from a single tooth accidentally picked up in the sand, determine the order of animal to which it belonged, whether herbivorous or carnivorous. The well-known relation between the teeth and the habits of animals, enables us to classify animals of which only the remains are found in rocks and caves of the earth—animals whose species has long been extinct.

To see fully the wisdom in the relations between the teeth, and, indeed, digestive organs generally, of animals, and the kind of food on which they live, we should consider how various is the food of animals. Only a limited number of beings can subsist on the same kind of food without soon exhausting the supply. Therefore, God in his wisdom has given different species of animals different tastes, thereby vastly increasing the number that can be supported on the earth. Then he has adjusted the teeth of each species to the kind of food forming its appropriate nourishment. Here we see, first, the existence of a particular species of food; secondly, an animal designed to feed on it; thirdly, an instinct in the animal directing him to the food; and lastly, a set of teeth adapted to that kind of food. A failure in the adjustment of either of these relations to the others would defeat the whole design. But failure at any point occurs not in the works of God.

117. *Relation between the teeth and the food of man at different stages of life.*—In early infancy milk forms the only suitable food for man. At that age there are no teeth to cut, tear, and masticate flesh. Had God designed infants to eat meat, he surely would have given them teeth to chew it. As soon as the teeth begin to appear, a small quantity of solid food may be allowed.

Here we see relations between the provision of milk by the mother and the digestive powers, together with the wants of the constitution, of the child.

118. *Teeth prospectively formed.*—Though the teeth are kept back in infancy, as they are not then needed, and might be much in the way, yet the rudiments of them exist in the jaw, ready to be developed at the right time. This is what may be called a prospective contrivance—a provision to meet the wants of the system at a future time. This exhibits design. There are other examples of the same nature in the structure of animals. The lungs are

of no use when formed ; for the child does not then breathe. The eye cannot then see ; for there is no light in the hidden parts where man is formed in secret. But still these organs, adapting the being to a new condition of life, are then developing for future use.

119. *Renewal of the teeth.*—Beautiful is the provision for furnishing a new crop of teeth. The jaws increase in size ; but teeth never grow after they are once formed. The teeth of infancy, therefore, become, even in childhood, too small for the increased size of the jaw. Were there no provision for adjusting the teeth and jaw to each other, great inconvenience would be experienced through life. But all this is provided for even in the embryo state of existence. The rudiments of the second crop of teeth, on a much larger scale than the first, are formed before birth. Were they sent out then of their proper size, there could not be sufficient room in the jaw for them. They are therefore kept back till the jaw grows, and the first set come forth and answer the purpose for a few years. As early, however, as is consistent with the design, the second set push the first out and take their place. Though they never increase in size, after they are once fairly developed, yet they set themselves so close in the jaw as to remain sufficiently near together when the jaw has acquired its full size.

120. *Saliva.*—It is exceedingly difficult to swallow perfectly-dry food, however effectually it may have been masticated. To remove this difficulty we are provided with organs which prepare a peculiar liquid called saliva, and which pour this fluid into the mouth as near as possible to the grinding surfaces of the teeth. The organs which form the saliva are called glands, from a Latin word signifying *acorn*, because they in size and shape are supposed to resemble an acorn. These glands are so placed, that the motion of the jaw in chewing compresses them and stimulates them to action. The faster, therefore, you chew, the harder they work.

The beauty of the design here appears in furnishing within the cavity of the mouth a fountain of fluid precisely adapted to the wants of the animal, and in providing that its flow shall be sparing or abundant according to the nature of the food and the degree of chewing it requires.

121. *The pleasures of taste.*—Every one knows that food is pleasant to the taste—at least most kinds of food are. But the pleasure is felt only so long as the food remains in the mouth; for the stomach is not an organ of taste. Man, therefore, is prompted to retain the food under the process of mastication as long as may be, by the pleasure which the very act of chewing affords him. And mastication, we have seen, (§113,) is necessary to digestion.

Herein divine Goodness has provided man with a source of pleasure, and divine Wisdom has thereby secured the due performance of the necessary work of mastication.

122. *Passage of the food from the mouth to the stomach.*—At the back part of the mouth there are three passages—one to the nose, one to the lungs, and the other to the stomach. It is important that the food, when prepared for swallowing, should take the right direction; for, to say nothing of the fact that food in the lungs or nose would be useless, every one knows what an unpleasant sneezing or coughing the accidental admission of food to the nose or lungs occasions. There are, therefore, against such accidents provisions, which, with proper care on our part, are generally effectual. The passage of food to the nose is prevented by a movable fleshy fold, or valve, hanging from the palate, and to the lungs by a cartilaginous lid, or covering, called the epiglottis. And, what is the result of great skill, the muscles which close the valves in the passages to the nose and to the lungs, are so related to those which are concerned in swallowing, that one and the same stimulus acts on them all. Whenever, therefore, the muscles of swallowing are excited to action by the presence of food, the

presence of the very same food excites also to action those which close the valves of the passage to the nose and to the lungs. A different arrangement might have produced very inconvenient results.

123. *Swallowing an involuntary operation.*—We have spoken in the last paragraph of the muscles of swallowing as being stimulated to action by the presence of food. We have seen (§89) that the susceptibility of being stimulated to action by the mere presence of a foreign body is the characteristic of an involuntary muscle. It would seem, then, that the act of swallowing is involuntary. Such, in truth, is the fact. Receiving food into the mouth is voluntary, chewing is voluntary, rolling the chewed food back to the opening of the throat is voluntary; but when once the food touches the muscles concerned in swallowing, they immediately contract, and we cannot help swallowing.

Is there any design in making these muscles independent of the will? And is the design wise and good? My attention was first directed to the involuntary character of these muscles by administering a few drops of water to a dying child, just before her last breath, and while she was under the influence of such inflammation of the brain as I knew must have destroyed all power of volition and consciousness. I perceived that as soon as a drop touched the muscles she readily swallowed. I of course thought nothing of the matter then; for my heart was broken, and my thoughts scattered; but reflecting on it afterward, I perceived the truth to be, that those muscles would always act, until paralyzed, regardless of will or consciousness. No doubt this involuntary power was given them to preserve the life of man, when, as it often happens, by accident or disease, he may remain for many days unconscious. Man can, therefore, swallow, and thus his life be sustained, while he has no power of volition or consciousness.

124. *The stomach.*—Though the health of the body

requires a constant supply of nutriment, yet it is best promoted by taking food at regular periods, followed by intervals of repose. The stomach is, therefore, designed as a receptacle of food. But this is by no means the whole nor the chief purpose of this organ. In the process of digestion it performs a more important part than any other organ.

The stomach in man is a bag, or sack, holding about one quart, situated at the upper part of the abdomen, extending across what is called the pit of the stomach. It has two openings—one for the admission of food, and the other for its passage to the bowels. The orifice giving passage for the food into the intestines is situated at the highest part of the stomach, so that the digested food passes out, not by its own gravity, but by a peculiar motion of the muscles on the coat of the stomach. While the process of digestion is going on, the passage of the food into the intestines is prevented by a sphincter muscle, (§98,) which closes the opening. But as soon as the work of digestion belonging to the stomach is accomplished, the muscle relaxes, and the food is thrown out. Is it not curious, that, so long as the stomach has any thing to do with the food, it should have power to keep the outlet closed fast, but, as soon as its work is done, it should open the gate, and let the food out?

125. *Change produced on the food in the stomach.*—The food is changed, while in the stomach, to a substance called chyme. This substance is a kind of pulp, somewhat resembling a mass of crackers soaked in milk, and perfectly mixed and incorporated, so as to be of uniform consistency. Its color is not always the same, but partakes slightly of the color of the food eaten. It is always of a light, or grayish color, varying, in shade and appearance, from cream to dark-colored gruel. It is always of the same appearance throughout. Thus, whatever may be the varieties of the food taken into the stomach at any meal, the whole becomes per-

fectly mixed and incorporated into one, uniform substance, so that it is impossible to discern any difference between what had been meat, or bread, or fruit. Yet the chyme at one time may appear different from the chyme at another time, and this difference may be caused by difference of food; but yet the whole mass, found at any time in the stomach, is all alike. It would be just as well, therefore, if you will eat many varieties of food at the same meal, to mix them all in one dish. They will mix in the stomach.

126. *How this change is produced.*—This change is very remarkable. Whatever is taken into the stomach, if it be at all suitable for food, is reduced to a uniform mass. Bones are reduced to a soft substance. Milk is first curdled, and then again softened and mixed with the products of the more solid materials. Meat and vegetables are worked over, and resolved into the very same elements. All this is effected by means of a peculiar fluid, which the stomach itself prepares, and which acts on food in the same manner as water acts on salt, dissolving it, or as alcohol on camphor, or, more properly, as acids act on metals. This fluid is called *gastric juice*.

127. *The properties of the gastric juice a special endowment.*—Various attempts have been made, by great and learned men, to account for the wonderful properties of the gastric juice—properties by means of which it converts the crude food into a substance so different from the materials of which it was formed, and so perfectly adapted to the purposes of life. The gastric juice presents to the eye nothing peculiar in appearance. It is a clear, transparent fluid. It has no odor. To the taste it appears a little saltish, and slightly sour. On chemical analysis it appears to contain muriatic acid, and some few other common substances, such as potash, soda, and lime. There is nothing, therefore, either in its physical appearance or chemical composition, to account for its peculiar properties. We are

inclined to regard the properties of this fluid as a special endowment, bestowed by divine Wisdom on this, and this alone, for a specific purpose. There are several facts connected with the conditions and effects of the gastric juice which display intelligence, design, and wisdom, which we will endeavor to present.

128. *Its solvent power.*—The solvent properties of the gastric juice differ from those of any other solvent known in nature. It acts indiscriminately on all articles forming the appropriate food of the animal in whose stomach it is formed. But, though there is not the slightest perceptible difference in the appearance of the fluid taken from the stomach of different species of animals, yet that in the stomach of one species does not act readily on the food used by another species: for example, the gastric juice of the cow will digest hay or grass, but will not act readily on flesh. That of a carnivorous animal will digest flesh, but not grass. That of man acts on nearly every thing. Now, who can give any mechanical or chemical reason why these differences should exist in the power of what appears to be precisely the same fluid? Do we not see here the relation between the gastric juice, the food, the taste, and the teeth of each species of animal? and could any wisdom, less than divine, adjust these relations? It is also known that most solvents act only on one species of matter. Water dissolves salt, but not gum. Alcohol dissolves gums and viscous substances generally, but not metals. Acids dissolve metals, but not all metals equally. But there is, probably, not a substance, within the whole range of the animal and vegetable kingdoms, beyond the power of the gastric juice. Though the stomach of man will digest some kinds of food much more easily than it will other kinds, yet it is doubtful whether there is any vegetable or animal substance on which his gastric juice will not act.

Let the wise men of the east, and the west, and the

north, and the south, combine their skill, and present us, either from nature or art, if they can, any other universal solvent. We have remarked that the gastric juice does not act on all substances with equal ease. There are some vegetables and some species of animals which prove, when eaten by man, digestible but in part. These substances are, in different degrees, poisonous, and derange the system. Minerals are wholly indigestible, and, when swallowed, derange the system more or less. Indeed, all mineral matter requires to be organized in vegetation before any animal can use it for food.

Is any design discernible in the existence of indigestible and poisonous substances? Were you aware that all our most active and most valuable remedies for disease are derived from vegetable and mineral poisons, and that they owe their efficacy as medicines to their poisonous properties? Administered by skillful hands, in proper circumstances, and proper quantities, they are medicines, and prove useful. Administered unskillfully, and in excessive quantities, they are poisons, and prove fatal.

129. *It has no power over living matter.*—Powerful as is the action of gastric juice on all articles of food, yet it is wholly ineffective on living matter. Living worms exist in the stomach unharmed, but if one die, by other means, the gastric juice uses it up at once. Oysters swallowed alive might live on, for all the gastric juice could do. They, however, would die for the want of breath, and then become subject to digestion.

The design of this curious law is evident. Could the gastric juice act on living as well as dead matter, it would digest and destroy the stomach itself. But what wisdom was required in executing the design! Living matter has not the power of resisting all solvents. Acids act on the animal body with great avidity, utterly destroying the texture of the skin, flesh, and bones. Yet the gastric fluid,

more powerful, in its sphere, than any acid, distinguishes, in a wonderful manner, between the living and the dead.

130. *Provision for forming it as it is wanted.*—The gastric juice is secreted—that is, formed, or manufactured—by certain organs on the inner coat of the stomach. These organs, like the involuntary muscles generally, (§89,) act independent of our will, through the influence of stimulus caused by the presence of foreign substances. If, then, the stomach is empty, these organs are quiet. No fluid is formed. As soon as any substance, however, is introduced into the stomach, they begin to work. They seem to be stimulated by the mere presence of any foreign matter. The existence of organs for the specific purpose of providing this fluid in the very place where it is wanted, and the susceptibility with which those organs are endowed of being stimulated to action by the mere presence of the substance to be digested, are surely evidences of divine wisdom.

131. *Hunger a special endowment.*—Many theories have been proposed for explaining the cause of the sensation of hunger. Some have supposed it came by the friction of the coats of the stomach when empty. Others have ascribed it to the irritation of the gastric juice, or the action of the liver on the adjacent parts. Dr. Beaumont ascribes it to the distention of the vessels that secrete the gastric juice. But it appears to me that hunger, so different from any other sensation—producing feelings in no way resembling those caused by the distention of the vessels of other organs of the system—should rather be considered a special endowment of the stomach. We have seen (§43) that susceptibility of pain is not a necessary result of organization, but only a special endowment of particular organs, bestowed for a wise and benevolent purpose. Each organ is susceptible of pain only from some particular condition which might endanger its functions. The muscles and tendons are scarcely susceptible to pain from sharp instru-

ments, but are exquisitely alive to straining, that being the species of injury to which they, from their position and office, are most liable. The heart is not sensible to touch, but is to the delicate derangement of the circulation. The optic nerve is insensible to mechanical violence, but is seriously affected by excess of light.

Hunger is a species of pain. The stomach only can feel it. God, in his wisdom and goodness, has endowed the stomach with susceptibility to this particular species of pain, excited by the want of food, in order to warn us of the danger which abstinence must surely produce.

132. *Motion of the stomach during digestion.*—The gastric juice, like other solvents, acts only on the surfaces of food. We have seen (§113) that food should be comminuted by chewing, in order to become accessible to the digestive fluid. But as the food, when swallowed, forms a mass in the stomach, provision is made to secure a thorough mingling of the fluid with it. This is effected by a peculiar motion of the stomach. This motion is performed by muscles placed for that purpose on the coats of the stomach, and susceptible of excitement to action by the presence of the food. By this motion every particle of aliment is successively brought into contact with the fluid. In addition to this churning motion, there is another called the peristaltic, or vermicular, because it resembles the motions of certain species of worm. This motion seems designed to throw the digested food forward in a spiral. As before remarked, (§124,) the passage from the stomach to the intestines occupies a higher position than any other part of the organ, so that to reach it the food has to ascend contrary to the law of gravitation. This is effected by the spiral motion of the stomach.

133. *Changes of the food in the intestines.*—As soon as the food is properly reduced to chyme in the stomach, it passes into the intestines. It here undergoes further

changes, the better adapting it to the purposes of life. The most important of these changes appear to be effected by the bile, which is a well-known fluid, usually called gall, formed by the liver, collected in the gall-bladder, and poured into the intestines, as it may be needed to complete the process of digestion. The bile is a peculiar fluid, possessing an alkaline property, capable of neutralizing acids. Hence, if the chyme contain acids, which might prove irritating and injurious to the delicate organs of the bowels, the bile neutralizes them, rendering them inert and harmless. The chyme is separated, probably by the influence of the bile, into two parts. The one part contains all the principles in the food capable of nourishing the body. It is a fluid, much resembling, in color and consistence, milk, and hence called chyle, from a Greek word signifying milk. Its composition and general properties are nearly the same as blood. The other part of the chyme is the worthless part, not suitable for nourishing the system. This is sent along down the intestinal tube, and thrown out of the body.

When we are in health, the separation between the nutritious and innutritious portions of food is perfect, no nutritious particles ever being found in the excrements. The means by which this work is accomplished are wonderful, but are not sufficiently well understood to develop clearly the beauty of the design, and the wisdom of the execution.

134. *Course of the chyle.*—All along the inner surface of the intestines are the rootlets or mouths of innumerable little vessels called lacteals, from a Latin word signifying milk, because they absorb the chyle, which has been compared (§133) to milk. The lacteals secure all the chyle as it passes along the intestines. Their orifices are very small, but their number is incalculable. They form a perfect net-work all along the intestines. They unite in larger and larger vessels, till they form trunks of considerable size.

They pass along between the folds of a very fine and delicate membrane, called the mesentery, which connects the intestines with the spine. In the mesentery the chyle passes through several glandular bodies, called the mesenteric glands, which, probably, modify it the better to prepare it for its conversion into food. From the mesenteric glands it is conducted, by a continuation of the lacteals, into a vessel called the receptacle of the chyle. From this receptacle, in which the chyle is collected by the lacteals, there is a tube called the thoracic duct, passing along upward in front of the spine. This duct conveys the chyle to the point where it is to be delivered into the current of the blood. The delivery takes place at the angle where two veins unite. These two veins are the jugular, which brings the blood from the neck, and the subclavian, which conveys the blood from the arm. At this point the chyle mingles and loses itself in the blood, just before the blood enters the heart, from which it is to be distributed for nourishment to every part of the body.

125. *Evidences of design in the course of the chyle.*—The evidences of design are far less clear in this part of the digestive system than in the stomach, simply because we do not so well understand the physiology of the operation. The parts of the body, in which this work is performed, from their situation and the minuteness of some of the organs, are not easy of examination, and much obscurity yet rests on the whole matter. We may remark generally, that because we do not see design exhibited in any particular part of nature's work, we are not to conclude that design does not really exist. Nor, because we do not know the use of a particular organ of the body, are we to suppose it has no use. In all these cases we are unable, from the imperfection of human knowledge, to see the perfection of the works of God. Future investigation, under the increasing light of science, and by the aid of art, may

reveal to the Christian philosopher design, beautiful, wise, and good, where it is now least suspected.

While, therefore, we cannot, with our present light, look clearly through some parts of nature up to nature's God, yet we may hope the day will come, when the darkness will be dispelled, the obscurity be cleared away, the vail removed, and we, with wonder and delight, behold the Hand divine in the hidden recesses where now no light shines. Indeed, it is a wonder that we know so much. The mere fact that the human mind has proved able to comprehend so much of the works of God—so sublime, so vast, so deep, so wise—is itself an evidence of consummate wisdom and power in Him, who made mind as well as body.

But, while the part of the digestive system, of which we have just treated, is not in all its particulars well understood, yet there does appear evidence of design in several particulars.

(1.) The roots or mouths of the lacteal vessels are exceedingly minute; so small, indeed, as to be wholly imperceptible by the most powerful microscopes. It is only after several of the roots have united and formed a larger trunk, that those vessels can be detected. The design of this infinitesimal division of the lacteal vessels, is to prevent their taking up any gross particle of matter, which might, from its size and weight, lodge in the passages. It is only the most comminuted particles of matter that can enter a lacteal.

(2.) The small size of each is compensated by the incalculable number of lacteals. So numerous are they all along the inner surface of the intestines, that, when the body is in health, not a particle of nutritive matter escapes them.

(3.) There have been various theories advanced to explain the rise of the chyle up the thoracic duct. Most physiologists have supposed that mere pressure, from the action of the muscles in respiration, and other motions of the body,

was sufficient to account for the passage of the chyle up in opposition to gravitation. But it is more probable that the Creator has provided a more safe and certain means of effecting this important work. The thoracic duct is furnished with a system of muscles, producing, by their alternate contraction and relaxation, a peristaltic, or species of spiral motion. By this motion the chyle is urged along the tube, while there are innumerable valves to prevent its returning.

We may here remark, that it is doubtful whether the fluids in the human body are at all subject to the common law of gravitation. Or, if the vital fluids within the system be influenced by gravity, equally with substances on the surface of the earth, the vessels in which these fluids flow are endowed with a special power of urging forward the matter they contain, regardless of the impediment arising from gravity. It is as if the channel of a great river had a vital power of throwing its waters up hill, by a force which should set gravitation utterly at naught.

(4.) The chyle unites with the blood at an odd place, to use the expressive epithet of Paley. The thoracic duct empties its contents into the blood at a point near the heart, where two large veins meet. It is as if, at the most southern point of Illinois, near Cairo, at the very point where the Ohio and Mississippi unite their waters, another small stream should put in between them. The Mississippi may represent the great jugular vein, bringing blood from the head; the Ohio, the subclavian vein, bringing blood from the arm; and the thoracic duct comes in, bringing a milky fluid. Now, suppose that it is but a short distance, a mile or two only, between the place of meeting of the waters of the Ohio and the Mississippi with the small stream we have described, and the great ocean, and you have a pretty good illustration of the local arrangement of this important apparatus. There is a valve at the mouth of the thoracic duct,

utterly precluding the possibility of the entrance of a particle of blood, but allowing free egress to the chyle. A very short distance only is to be passed, until the commingled fluids are poured into the heart, the great living ocean, whose beating and surging give life and activity to the whole system.

136. *Structure and design of the lymphatic vessels.*—In addition to the lacteals, there is another set of vessels, precisely similar in their general character, having their roots in every part of the body—at the surface, and in the inner parts of every muscle, and bone, and tissue, of every kind in the system. These vessels are called lymphatics, from a Latin word signifying water; because, instead of carrying a milky substance, like the lacteals, they carry a fluid resembling, in appearance, water. On analysis, however, the chyle and the lymph appear of very nearly the same properties, and both differ but slightly from blood. A portion of the lymphatics pour their fluid into the thoracic duct, with the chyle, and another portion deliver theirs over to another duct of similar character to the thoracic, on the other side of the body, to be mingled with the blood at the junction of the right jugular with the right subclavian veins, and thus to meet at the heart with its kindred stream from the left.

The lymphatics answer a most valuable purpose in the animal economy. Indeed, on their action the preservation of life often depends.

We have shown (§19) that the continued functions of living beings demand, for some reason not known, a continual change in the matter composing the body; that decay and renewal are indispensable to life; that, so frequent is the change, so rapid the work of decay, but a few years are necessary to effect the complete removal of every particle of the body, with the substitution of new matter for the old.

Whenever a particle of the animal body becomes old, or has done its work, or begins to decay, the organs of the lymphatic system immediately proceed to digest it. As the stomach breaks down and dissolves the matter received for food, and the intestines separate it into chyle and excrement, the one to be taken up by the lacteals for nutrition, the other to be expelled, so the organs of the absorbing system soften down and dissolve the old and decaying particles of the body, separate the matter into two parts, the one to be given over to the lymphatics for nutrition, and the other to be carried off by the veins and thrown out of the body by means of the kidneys, lungs, skin, and other excrementary apparatus. Thus, the very decay of the body becomes the means of its renewal. Old matter is worked over into new. Nothing is lost, except what is totally unfit for nutrition; and that is thrown away, so as to do no harm.

The design of thus making the animal body contribute to its own nourishment—of securing food for the whole out of the inevitable decay of particular parts—is most wise and benevolent. It is to provide against the loss of life by temporary abstinence or sickness. In disease the digestive organs do not usually perform their functions well, and the system receives little nourishment from food. But the absorbent system keeps at work, and the lymphatics carry nutrition to the blood, with little, if any, diminution of efficiency. The fatty portions of the animal body become, in disease, food for the absorbents. It is frequently all used up to support life, so that the animal becomes lean. If disease or abstinence continue, the more solid tissues of the system fall a prey, and emaciation goes on to a great extent, before the powers of life give way. We thus see a remarkable provision to secure us from the fatal effects, which must otherwise follow the temporary suspension of nutrition from food. When we consider the frequent instances in which, from disease, no nutrition is furnished from food, we may

clearly see the beauty and benevolence of this wonderful provision.

137. *Complication of the digestive apparatus.*—No system of human organs appears so complicated and various as the digestive. We see the lips, teeth, saliva, stomach, gastric juice, liver, bile, intestines, lacteals, and lymphatics, all combined in successive and harmonious action to effect the great work. Every kind of agency, mechanical, chemical, and vital, seems to be employed. But the digestive organs of different animals vary in complicated structure and function, in proportion as the natural food of each animal requires greater or less changes to adapt it to the purposes of nutrition. The flesh of dead animals obviously requires less change to assimilate it to the living animal body, than do vegetables. And we find the digestive organs of carnivorous animals quite simple, and those of animals feeding on vegetables very complicated. The stomach and intestines of most fishes, which feed on one another, form but a simple straight tube, while those of a sheep, living wholly on vegetables, are about thirty times the length of the body. Man, being an omnivorous animal, feeding on flesh, and fish, and fowl, and creeping things, and grass, occupies a medium place between the simplicity of the wholly-carnivorous, and the complexity of the wholly-gramnivorous species.

In these adaptations and relations between the mode of life, kind of food, and digestive organs of each species, may be seen curious exhibitions of wisdom.

LECTURE VII.

STRUCTURE AND DESIGN OF THE HEART, ARTERIES, CAPILLARIES,
AND VEINS.

Distribution of nutriment—The blood—The heart—Harmony of action in the heart—Difference in strength of the two sides of the heart—Action of the heart involuntary—Reason why exercise increases the frequency of contraction—The heart insensible to touch—Frequency of contractions—Condition of the heart in fainting—Valves—Arteries—Structure thereof—Design of their elastic properties—Design of their contractile power—Protection of the arteries—Provision for furnishing every limb and every organ with a due supply of blood—Provision against injury to the delicate organs of the body by the impetus of the circulating blood—More blood furnished the right than the left arm—Capillary vessels—Changes of blood in the capillaries—The veins—Structure thereof—Motion of blood therein.

138. *Distribution of nutriment.*—We have seen, in the last lecture, that all the nutriment designed for the whole body, reduced to the fluids we have described, as chyle and lymph, are poured into the blood near the heart. In the heart these fluids become perfectly mixed with the old blood, and are lost like streams flowing into the great ocean. Indeed, the chyle and lymph become new blood. It is in this way that the supply of food is kept up. Before birth our blood is furnished us from the heart of our mother. And when we enter on an independent state of existence we receive from our mother blood sufficient to begin life with, and to enable us to set up business for ourselves. In a few moments, however, the link that united us physically to our mother is broken, and we can receive no more ready-made blood from her. We must now begin to manufacture for ourselves. Our mother for some months still continues to furnish material, but our own stomach must do the work. After a year or two she gives up even that, and we have to obtain nutriment elsewhere. But we usually find sufficient

for the purposes of nature, and the supply of blood is kept up through life.

139. *The blood.*—The blood contains the essence of all the nutriment derived from food. It is the common material of which all the body is built up. It is equally requisite for the construction of the most delicate membrane, and of the hardest bone. It gives origin to the blandest fluid, and to the most powerful solvent known in nature. The skin, nails, hair, bone, muscles, nerves, and brain, are all made of blood, and kept in repair by blood. It is the warp and the filling, from which every tissue is woven—the raw material, from which every bodily organ is manufactured.

The general appearance and obvious properties of the blood are too well known to need description for the general purposes of these lectures. We will, therefore, pass on to describe the structure and adaptations of the wonderful apparatus by which the blood is distributed to every portion of the body, by a constant round, called the circulation.

140. *The heart.*—The heart is the great, untiring engine, of wonderful power and vital energy, by whose incessant action the circulation is kept up. The heart is a muscular organ, having four chambers—two on the right, and two on the left side. The two chambers on the right are separated from those on the left by a firm partition, admitting of no communication. Into the first chamber on the right, called the right auricle, the blood flows from the veins, carrying, as we have seen, the chyle and lymph along with it. This auricle suffers a limited degree of extension, until, excited by the presence of the blood, its muscles contract, and throw the blood into the second chamber, called the right ventricle. This, in turn, contracts, and throws the blood into the lungs for purification. The blood, after passing through the pulmonary veins and arteries, reaches the left side of the heart, and enters the first chamber of that side,

called the left auricle. The contraction of the muscles of this auricle throws the blood into the next chamber, called the left ventricle. This, in turn, contracting with great power, throws the blood through the arteries to every part of the system. By the veins the blood returns again to the heart, to go the same round, till life shall end. To sum up the series of actions of the heart: the right auricle receives the blood from the veins, and sends it into the right ventricle; the right ventricle sends it to the lungs; the left auricle receives it from the lungs, and sends it to the left ventricle; the left ventricle sends it over the body. These four contractions, however, do not require four distinct periods of time. There are only two. The two auricles contract at the same moment, and so do the two ventricles. At the same moment, therefore, one portion of the blood is sent to the lungs, to be purified, and another portion, having been purified, is sent over the body. These contractions of the muscles of the heart give rise to what is called *beating of the heart*.

141. *Harmony of action in the heart.*—It is wonderful that the blood returning from the lungs, and that returning from the body, and in each case flowing continuously, should fill their respective auricles to the point producing contraction at the same moment. This exhibits a mutual relation between the action of the heart, arteries, and veins, that is truly surprising. The muscles of the whole circulating system seem to be governed by the same invisible influence, and all to concur in the same general end, and establish the most beautiful and perfect harmony of action.

142. *Left side of the heart stronger than the right, and design thereof.*—Anatomists will tell you that the left side of the heart, especially the ventricle, is much stronger than the right; that its walls are much thicker, their texture much more dense and compact, and evidently capable of a much greater degree of exertion.

This is as it should be; for the right ventricle has only to propel the blood a short distance—to the lungs—while the left has to send it all over the body, to every extremity, and through every variety of texture. The power in each case is precisely equal to the resistance to be overcome; for, as we have seen in the last paragraph, the circulation over the body is performed in the same time as that through the lungs.

The walls of the ventricles are also much thicker, and the muscles much stronger than those of the auricles, for the plain reason that they have to propel the blood, by their contraction, through a system of remote vessels, while the auricles have only to transmit the fluid which has been thrown into them by the veins into the ventricles, which dilate of their own accord to receive it.

143. *Action of the heart involuntary.*—The muscles of the heart are, as we have before said, (§87,) involuntary. We have no control whatever over them. The mere presence of the blood stimulates them to action. The chambers of the heart passively receive the blood, and suffer themselves to be distended to a given degree, before the stimulus is sufficient to produce contraction. When, however, the dilation reaches the fixed limit, the heart contracts suddenly, with great force.

144. *Reason why exercise increases the frequency of contraction.*—Every one knows that violent exercise greatly increases the action of the heart. The physical cause depends on the increased flow of blood in the veins, from the pressure on them by the motions of the body, causing a more rapid flow of blood to the heart, thereby exciting it to increased frequency of action. The final cause depends on the necessity of more blood to sustain the life and power of the muscular system, under the drafts made upon it by exercise.

145. *The heart insensible to touch.*—We have remarked (§43) that the heart may be handled, and perhaps cut and

torn, without manifesting sensibility to pain. You may hardly believe this; but few physiological facts are better supported by good authorities. It is, however, keenly alive to every influence arising from the circulation, and is exquisitely sensible to the influence of the passions and emotions to the mind. The physical reason why emotions of the mind should affect the heart is not clear. Whenever we approach the connecting link between body and mind we lose our thread, and wander in the mazes of an inextricable labyrinth. We know there is a connection, but we cannot trace it. We simply know the fact, and that is all. So intimate, however, is the connection between the mind and the heart, that we often speak of affections of the mind as of the heart. We speak of a light heart and a heavy heart; a cheerful heart and a sad heart; a little heart and a great heart; a stout heart and a faint heart; a tender heart and a hard heart; a good heart and a bad heart.

146. *Frequency of contractions.*—In grown persons the heart beats about once every second; in children about twice as often. It is greater in the standing than in a sitting position, and in sitting than in reclining. It may be greatly increased, as we have said, (§144,) by exercise, and by mental emotions. Increased action in health is attended by no evil consequences, but in disease, especially of the lungs, violent exercise and mental emotion should be avoided. When disease of the lungs assumes such a form as to prevent the free passage of the blood through them, if the action of the heart be by any means increased in strength and frequency, there may be danger of rupture of the heart, or some of the large vessels, attended by immediate death. Is there any connection, exhibiting design, between this fact and the well-known tranquility of mind so strangely and uniformly attending the progress of pulmonary consumption?

147. *Condition of the heart in fainting.*—Numerous

causes which act violently on the nervous system, such as sudden injuries and violent mental emotions, weaken the action of the heart, so as to render it hardly perceptible. This is called fainting. The heart does not entirely cease its motion, and proper stimulus seldom fails to restore the patient; but if efforts to revive circulation be delayed, death may result.

148. *Valves.*—The heart acts, in some respects, on the principle of the forcing pump. You may have a tolerably correct idea of its action by a very simple experiment. Place the palms of your hands at right angles across each other, interlocking the thumbs. Then take a small quantity of water between your palms, and press your hands suddenly together. The water will be forced out in a jet, much as it is by the action of the heart.

Action of this kind always requires valves. No species of forcing pump could work without them. When the piston of a common pump descends, were it not for the valve underneath, the motion, instead of raising the water, would only force it down. Now the heart, constituted as it is, can no more work without a valve than a pump can. The blood having returned from the general circulation, flows into the right auricle, from whence it passes into the right ventricle. The ventricle, dilating till it becomes full, suddenly contracts, with such force as would drive the blood back into the auricle, as well as forward into the lungs, were it not for the interposition of a valve, which freely admits the blood to pass onward, but denies all passage back. These valves are found in all parts of the vascular system, wherever their presence seems necessary, whether about the heart or in the arteries or the veins.

There is a beauty of design, and a neatness of execution about these valves, exhibiting the highest exercise of mechanical wisdom. So nice and delicate are they in structure and action, that it is difficult to give a clear idea of

them by any verbal description, without a diagram, and even with the best drawings it might still be difficult. They are formed of membranous folds, attached by one edge to the walls of the passage they are designed to guard, in such a manner that they rise and give free passage to the advancing current, but immediately close whenever the fluid returns. They act like flood-gates. We sometimes construct flood-gates on tide-water streams for the sake of accumulating a head of water to carry a mill. The flood-gate hangs on hinges by its upper edge, like a swinging sign. It, however, is so constructed as to swing only in the direction of the flowing tide. While the tide flows up the channel the gate swings open, and offers little or no resistance to the current. But when once the tide turns, and begins to ebb back, it mechanically closes the gate. Nothing can well exhibit more unequivocal evidence of design, contrivance, and skill. The current of blood could no more generate a valve than the mill-stream could make a gate. The valve was formed by infinite Wisdom on purpose to secure the current of blood from a back-set.

149. *The arteries.*—The vessels into which the blood is thrown from the heart, and by which it is distributed to all the extremities of the body, are called arteries, from a Greek word signifying to hold air. After death they are always found empty. The ancients, therefore, examining them only in the dead animal, supposed they carried only air, and, therefore, gave them the name, arteries. Arising from the heart, the fountain, by one trunk, they divide, subdivide, and resubdivide into innumerable branches, so as to carry blood to the most distant and most minute portions of the body. So perfectly do they penetrate every part of the body, that not even a trifling cut, scratch, or pinch, can be made without wounding some arterial twig. Some compare the arterial system to the trunk, branches, and twigs of a tree. Paley compares it to the apparatus for

furnishing water to a city. In Philadelphia, New York, and Boston, are water-works. At some convenient point in the city is a large reservoir of water. From the reservoir runs a large pipe, and from this pipe smaller ones branch off, putting out at convenient places, so as to carry water to every street in the city, and every house on the street, and every room in the house. But the apparatus for circulating the blood is much more beautiful and wisely-constructed than the water-works of any city in the world.

150. *Structure of arteries.*—The arteries are, by their structure, wonderfully adapted to the purpose for which they are designed. They consist of three coats. The inner is a continuation of the membrane which lines the interior of the cavities of the heart. It is smooth, polished, and lubricated by a thin fluid, so as to prevent friction. Yet, though thin, it is so firm and strong as to secure it against rupture. The external or outer coat consists of small fibres, very dense and tough, and interlaced in every direction so as to afford strength to the artery.

But the structure of the middle coat is the most interesting and important. It is formed of several successive layers of circular fibres. The fibres run, not lengthwise, but around the calibre or channel of the artery. This coat is distinguished from the others by its contractile power.

151. *Design of the elasticity of the arteries.*—The arterial coats are peculiarly elastic; that is, they yield and stretch on pressure. The design with which this endowment was bestowed we will explain. (1.) To diminish friction. It is well known that the heart forces the blood into the arteries by impulses. If the arteries were inelastic tubes, such as the wooden or metallic pipes of water-works, there would be great loss of force from friction. But by using elastic tubes friction is greatly diminished. (2.) To prevent bursting or wearing. The great force with which the heart throws out the blood might burst an inelastic artery, especially near the

heart. But if the artery did not burst, its walls might be rapidly worn away. "The waters wear the stones." No inelastic substance could long resist the action of an impulsive stream. The giving and yielding character of the coats of the arteries secures them against all these inconveniences. It is remarkable, too, that the elasticity is greatest near the heart, and diminishes gradually toward the extremities, where it nearly ceases. This is as it should be; for elasticity is obviously most needed near the heart, where the danger of rupture and friction is greatest.

152. *Design of the contractile power of the artery.*—The blood being sent from the heart by an impulse, as soon as it reaches the arteries several retarding causes begin to operate, through which the velocity at first imparted to the current gradually lessens. The friction between the blood and the sides of the artery, partly but not wholly overcome by elasticity, the winding course which the blood must take in passing over the angles and around the curvatures of the body, and the pressure of the muscles and heavy parts of the body on the arteries, present obstructions of such influence as would render it impossible for the heart, without assistance, to conduct the circulation. Therefore, on the artery, as well as on the heart, is bestowed the power of contraction. The muscles of the arterial coat, like those of the heart, are involuntary, and are excited to action by the stimulus afforded by the blood. It is on this account that they are found empty after death, having, by their last contraction, thrown all the blood they contained into the veins.

It is remarkable, too, that in the artery the power of contraction increases as the vessel proceeds from the heart. It is greater in the small than in the large arteries, and greater still in the capillaries which are at the greatest distance from the heart. The design of this is evident; for as

the strength of the heart's impulse on the blood diminishes as the current leaves the fountain, so the strength of the contractile power in the small arteries, through which it has to pass, should increase. A large artery, near the heart, needs not much contractile power, because the heart's action is sufficient; but, as the momentum of the beating heart diminishes, through the influence of retarding causes, operating with accumulating effect, increasing power in the artery is indispensable, as a compensation for the decreasing influence of the heart. Could any design be more obvious, or its execution be more skillfully accomplished?

There is still another purpose effected by the contractile power of the arteries: it is, to arrest bleeding from wounds. When an artery is wounded, the blood spirts out. Soon, however, the muscular fibres of the artery contract, close the opening, and arrest the flow of blood. Were it not for this, we might bleed to death from a slight puncture or scratch. In amputating a limb, the surgeon need tie only a few of the larger arteries. The smaller, by contraction, secure the patient against danger from bleeding.

153. *Protection of the arteries.*—Though, by their contractile power, the danger from wounding the smaller arteries is greatly diminished, yet, as this power is insufficient to arrest bleeding from the larger trunks, the greatest possible care has been taken to protect them from accident, by placing them in circumstances in which external force can hardly reach them. The great trunks are uniformly situated in the great cavities of the body, or lie imbedded deep in the substance of the limbs. They pursue their way under shelter of the bones. Often they pass along in grooves hollowed out in the bones on purpose to receive them; and sometimes they pass through a channel, or complete tube of solid bone. When the arteries must, for the due exercise of their functions, approach the surface, they divide and

subdivide into smaller and yet smaller branches, until, when at last they reach the surface, they spread out into a network of exceedingly-minute vessels.

154. *Provision for furnishing every limb and every organ with a due supply of blood.*—It is indispensable to the maintenance of health, and even to the preservation of life, that every organ of the body should receive a due supply of blood. If any organ be deprived of its supply it dies. Two wise expedients are therefore adopted to guard against accidental interruptions of the circulation in any part.

(1.) In the first place, every important organ receives blood from more than one large trunk, so that if, by accident, one source be obstructed, another remains open. The brain receives branches from no less than four distinct sources.

(2.) In the second place, all the arterial branches have frequent communications with each other. Thus, at a certain point of an artery a lateral branch goes off to a parallel trunk. Passing along a short distance down this second artery, and another branch is found going back to the first. Thus, if an obstruction occur in one artery, the blood, instead of proceeding direct, has only to leave the main trunk at some convenient point above the obstruction, pass off by a lateral by-path into another channel, and after awhile return to its old road below the obstruction.

Much the same expedient has often to be adopted by the traveler in the west to get around a fallen tree obstructing his path.

Guided by a knowledge of the intercommunications among the blood-vessels, the modern surgeon safely performs operations which in former times would have been supposed inevitably fatal. In some cases it becomes necessary to tie a large artery so as utterly to obstruct the passage of blood in it. At first the limb supplied principally by that trunk appears numb and feeble, but in a short time the collateral branches above the stoppage enlarge, and transmit an

increased quantity, so the limb below the obliterated part receives as bountiful a supply as if nothing had happened.

155. *Provision against injury to the delicate organs of the body from the impetus of the circulating blood.*—There are parts of the body in which a large quantity of blood is needed, but whose texture is so delicate as to be ruined by the mere force of the blood, were it sent directly by the large vessels.

There are two beautifully-contrived expedients to guard the delicate structures, and yet furnish them the necessary amount of blood.

(1.) The arteries supplying the brain and other delicate organs are very meandering in their course. This winding about tends greatly to diminish the force of the current, and the stream enters gently, with a quiet, even flow.

(2.) Sometimes a large artery, just before entering a delicate organ, suddenly divides into a great number of minute branches, forming a perfect mesh or net-work of vessels. This arrangement must, on the well-known principles of philosophy, tend greatly to diminish the velocity and momentum of the blood.

Such contrivances are indispensably necessary in the most delicate of all the animal organs—the brain. Even now, with all the contrivances for protection, the brain is alarmingly liable to disease. While I am writing the intelligence is brought to my room of the sudden death of one of the most distinguished men of this nation, by a sudden flow of blood to the brain. Some few years ago I recollect of being startled by the news of the death of another equally-distinguished citizen of the same state in the same manner. In the living body the brain is semi-fluid; and were it not for the protection afforded it by the skull bones and membranes, it would be shaken to pieces by the slightest jar. Its delicate structure requires the utmost care in distributing the blood-vessels to it. After the arteries enter the cavity

of the skull, they do not immediately enter into the nervous texture of the brain, but first minutely subdivide on the membrane which closely invests its surface, and enter between its folds.

156. *More blood furnished the right than the left arm.*—It is a well-known fact, that the right arm is usually stronger than the left. Though a part of this superiority of strength is owing to education and exercise, yet the different mode in which the arteries are distributed to the two arms constitutes a natural source of inequality. The artery which supplies the right arm is the first that puts out from the main trunk, and proceeds from the heart in a more direct line than the one going to the left arm. It is therefore inferred that the right arm is originally better supplied with nourishment than the left, and was intended so to be for wise purposes. This opinion receives confirmation from the fact, that in birds, where any inequality in the strength of the two wings might have disturbed the regularity of flight, the main artery, when it has arrived at the centre of the chest, divides with perfect equality into two branches, so that both wings receive the same amount of blood. The muscles, being thus equally nourished, preserve the equality of strength which their function demands.

157. *Changes in the activity and capacity of the blood-vessels.*—We have noticed (§154) the changes in capacity occurring in the lateral vessels, when the main trunk happens to be obstructed. There are, however, other very interesting changes often occurring, admirably adapted to the changing circumstances of the body. The arteries of the impregnated womb not only adapt themselves to the increased wants of the enlarged organ itself, but furnish materials for the development of the young that it bears. In due time the vessels of the breast enlarge, so as to furnish an abundant supply of rich and nutritious food, precisely adapted to the digestive powers of the new-born offspring. What

beauty of relation as well as contrivance is here seen! There would seem no necessary connection between the organs that nourish the infant, in its embryo state, and those which furnish it milk after birth. These organs are not contiguous, nor have they any thing common in their structure or organization; yet God has been pleased to connect them by peculiar relations, and make them each, in due time, subservient to the same purpose, under very different circumstances.

158. *Capillary vessels.*—The capillaries are vessels finer than hairs, forming a connecting link between the arteries and the veins. In them the arteries all terminate, and the veins all begin. Thus the ultimate branches of the arteries are continuous with the commencing twigs of the veins. The capillaries form a net-work in every part of the body. In them all the phenomena of growth and nutrition take place, all the secretions are elaborated, and all the various tissues formed. The heart and arteries send along the blood—the raw material—to be worked, in the capillaries, into bone, muscle, nerve, or whatever other product, solid or liquid, the body may demand. The capillaries are the workshops to receive the material. In them are disposed all the manufacturing instruments which Nature uses in making man. In them, and through them, and by them, she performs her exquisite operations in molding, forming, and renewing this wonderful piece of workmanship—the human body. All the blood has to pass into some one of these vessels. They select out from it whatever quality and quantity may be suitable and necessary for nutrition, retain it, and send the rest along to the veins. The contractile power of the capillaries is very great, much greater than that of the arteries. They send along the refuse blood to the veins with considerable force.

In the capillaries the blood undergoes great changes. In the arteries it is bright red—in the veins dark purple. In

the arteries it is capable of nourishing the body—in the veins it is totally unfit for nutrition, both from the absence of nutrition and the presence of deleterious properties. Indeed, the remains of the blood, after leaving the capillaries and entering the veins, would be fatal to animal life, if suffered to re-circulate unpurified. It passes on through the veins without injury; but, if sent by the heart over the body again, in its unrenewed condition, it produces death. Therefore, the blood, after its first round in the system, is sent to the lungs, as we shall more fully explain in our next lecture, to be purified and renewed.

159. *The veins.*—On leaving the capillaries the blood enters the veins. The veins collect all parts of the fluid which the capillaries did not use, and carry it back to the heart. Thus, if we compare the arteries to the pipes for supplying a city with water, we may compare the veins to another set of pipes to carry the surplus water back to the reservoir. The blood thus makes a complete round, and hence is said to circulate.

160. *Structure of the veins.*—In structure the veins differ materially from the arteries. The external coat, affording so much strength to the arteries, is, in the veins, nearly wanting, and the internal membrane is only surrounded by a thin layer of longitudinal, loose, and extensible fibres. Their walls are thin, and collapse when not distended with blood. They are much less elastic and contractile than arteries. They are much more numerous than arteries. Were we to cut across a limb, and estimate the respective areas of all the veins and arteries, we should find the veins to exceed the arteries by two or three times. The veins also lie nearer the surface of the body than the arteries.

The reason of these differences in the two systems of vessels is obvious. In the veins the blood flows less rapidly than in the arteries. They receive the blood after the power of the heart's impulse over it is nearly exhausted. Not

much strength of wall, therefore, is needed to sustain pressure, and to avoid rupture. From the slow motion of the blood little danger is likely to result from wounds, and, therefore, they need not lie so deep in the body, nor be protected with so much care. Again: as the blood flows slower in the veins than in the arteries, no one vein of equal calibre with an artery can carry so much blood in a given time, and, therefore, the number of them is increased, as a compensation.

161. *Motion of blood in the veins.*—We have seen that the motion of blood in the arteries and capillaries is owing to the impulse of the heart and the contractile power of the arteries. The veins, however, are nearly, if not quite, destitute of contractile power; and the power of the heart is nearly expended before the blood reaches them. It becomes, therefore, a curious question to determine how the blood gets along in the veins, generally up hill, from the capillaries to the heart.

Several causes, acting in conjunction, may contribute to this motion:

(1.) The blood enters the veins with the remains of a small momentum derived from the heart and arteries.

(2.) The veins are very large, and freely communicate with each other, so that, if any obstruction occur in one tube, the blood may pass freely in another.

(3.) They are crowded with valves, which are so disposed as to offer no resistance to the flow of the blood toward the heart, but to render any other course impracticable.

(4.) The veins are so situated among the muscles that some of them must be compressed by every movement. This compression will force the blood forward, but not backward, on account of the valves. As soon as the muscles relax the vein will be refilled by blood forced in, through a posterior valve. Then another muscular movement will force it again forward. Hence, muscular movement becomes

a kind of universal heart, diffused over the whole body. We see, by this, the value and influence of exercise in promoting free circulation.

(5.) The veins are less tortuous and meandering than the arteries; so that the impediment from angles, curves, and lateral friction may be small.

(6.) The heart, and especially the lungs, may act as a kind of suction pump, and thus facilitate the passage of the blood to the cavities of the heart. If all these causes, and perhaps others, do combine to urge the blood forward, in the veins, to the heart, it is remarkable that the work is performed with so much regularity. We have seen (§141) that the venous blood from the body flows into the heart, so as to fill the right auricle at precisely the same moment when the purified blood from the lungs fills the left auricle. And it may be remarked, also, that both auricles fill up during the contraction of the ventricles. Now, there must be a very nice balancing of causes and wise adjustment of forces, to produce these effects at precisely the right instant. The more various and complicated the causes of motion in the system, the more wisdom is required to adjust all the forces, so as to produce the required result.

We have thus traced the blood in its round, and seen, in our progress, many indications of the divine Hand. We had seen more, if our means of observation had been better and our eye more clear. It may be that where we have seen least, there may prove to be most evidence of design and wisdom; but we have seen enough to induce us to admire and love the great and good Being who has made us, and provided so wonderfully for our preservation and happiness.

LECTURE VIII.

THE STRUCTURE AND ADAPTATIONS OF THE ORGANS OF RESPIRATION.

Respiration—Why we must breathe—What the deleterious matter of venous blood is—The breathing apparatus—The lungs—The trachea—The bronchial tubes—Course of the air in breathing—Adaptations of the breathing organs—Special adaptations of the trachea—Adaptations of the lungs—Course of blood in the lungs—Change of blood in the lungs—Changes of the air in the lungs—Nature of carbonic acid—Origin of carbon expelled from the lungs—Conditions of healthy respiration—Free action of the lungs—Constitutional deformity—Positions of the body—How expansibility of the lungs may be increased—Supply of fresh air—Carbonic acid—Malaria—Local causes of bad air—Cause of death by suffocation—Relations between respiration and circulation—Modifications of the respiratory organs—Torpidity.

162. *Respiration.*—We have often referred, in our last lecture, and, perhaps, in former ones, to the purification of blood in the lungs. It is known, by every one, that breathing is a vital necessity. No living thing—neither bird, nor beast, nor fish, nor insect, nor creeping thing, nor tree, nor blade of grass—can live without breath. To cease to breathe is to die; hence, the word *expire*, which means to breathe out, or cease breathing, has become synonymous with the word *die*. Important as is this operation, yet, no doubt, many persons have been breathing for many years, and keep on breathing still, without knowing, or ever inquiring, either how or why they breathe. We will first explain why we must breathe, and then show how we do it.

163. *Why we must breathe.*—We have seen (§158) that the blood undergoes, in the capillary vessels, between the termination of the arteries and the commencement of the veins, a change in appearance and properties. The change of appearance respects the color. It goes into the capillaries a bright red. It comes out a dark purple. The change of properties consists in the loss of nutritious qualities and

the acquisition of injurious ingredients. Therefore, if the venous blood be allowed to circulate over the body, without purification and renewal, it not only fails to nourish the body, but actually poisons it. No man, therefore, can live many minutes without breathing, unless circulation be also suspended. If a man falls into the water, under such circumstances as to suspend respiration, but yet permit the circulation to continue, he cannot live more than from three to five minutes, for the unpurified and vitiated blood will effectually paralyze the capillary vessels, and deaden the brain and nervous system. When once this occurs—when the venous blood has been sent, unrenewed, for a few times over the body—when once its poisonous, paralyzing influences have been suffered to operate—all efforts at resuscitation prove fruitless. But if fainting occur at the time of falling into the water, so that circulation, as well as respiration, is suspended, the apparent dead may be brought to life, even after some considerable time. I heard, the other day, of a child, that, in crying, for some trifling cause, held its breath, as is frequently the case with children, and died on the spot. In this case death was caused by the poisonous effects of the venous blood entering into the circulation.

In general, animals deprived of fresh air will live only until the small quantity of air remaining in the lungs is exhausted. Fishes, placed in a close vessel of water, will die as soon as the air absorbed in the water is exhausted. They will live but a few minutes in boiled water, for boiling drives the air out of water, as you may see by the escape of bubbles.

In all these cases, death results from the fact, that the impure blood circulating over the body acts as a fatal poison.

164. *What the deleterious matter of venous blood is.*—So far as the subject is at present understood, it appears that carbon, in some form, is the poisonous substance.

removed from the lungs, in breathing. As vegetables consist almost entirely of carbon, and all flesh contains it, a very large quantity enters our system in our food. The food, as we have seen, (§133,) is changed into chyle, which enters the blood, carrying its superabundance of carbon with it. The arteries carry the blood to the capillaries. The capillaries draw forth the nutrient principles of the blood, but they cannot use so much carbon. By their action on the blood, the surplus carbon, which, in the arteries, was so combined with other matters as not to appear, is left free, and sent along into the veins, giving the blood in the veins its dark color. When this venous blood reaches the lungs it is relieved by respiration of its load of carbonic matter.

You may ask if an easier method of getting rid of the carbon of the blood might not be admissible. Might not provision be made for the superfluous carbon to be ejected from the system at an earlier period, so as not to enter the blood at all? Perhaps the mere getting rid of the carbon might have been accomplished in some other way, less complicated than the process of respiration; but we shall find, as we proceed, that there is design even in this complication of action. This method of effecting the object has some peculiar advantages. We shall find that breathing is made subservient to the maintaining of animal heat; and, had some easier method of excreting the carbon been adopted, so as to dispense with breathing, I know not by what means animals could have maintained their temperature, independent of the changes of the atmosphere. In the present constitution of things, though the surface of the body may be affected by extremes of heat and cold, yet the internal temperature of the system remains the same under all circumstances.

165. *The breathing apparatus.*—The means of effecting respiration are various in animated nature. Trees breathe by their leaves, insects by the admission of air through

little holes in their bodies, fishes by gills, and the mammalia by lungs. Man is furnished with a splendid apparatus, evincing design, wisdom, and benevolence.

166. *The lungs*.—The most important part of the breathing organs of man is the lungs. These are situated in the cavity of the chest. We have (in §59) described the bones of the chest, and explained how the peculiar manner in which the ribs are joined to the spine and the sternum promotes the action of the lungs. The lungs are double, there being one on each side of the heart. They are joined, or rather there is a communication from one to the other, at their upper extremity, in what is called the windpipe. The two lungs nearly fill up all the chest not occupied by the heart and blood-vessels. Just below the lungs, forming the lower boundary of the chest, is a large and peculiar muscle, called the diaphragm, an organ designed to aid in the action of the lungs.

167. *The trachea*.—The trachea, or windpipe, is a tube situated in the throat, and running from the back of the mouth to the upper end of the breastbone. It is formed of a series of small cartilaginous bands, placed across in the form of incomplete rings. The interior is lined by a mucous membrane of the same nature as that of the mouth, being, in fact, a continuation of it. You may easily feel, at your own throat, the shape and size of these rings, and, indeed, obtain a good idea of the windpipe.

168. *The bronchial tubes*.—The trachea at its lower end, near where the collar-bone joins the breastbone, is divided into two prongs, like a pitchfork. These two prongs proceed one to each of the lungs. As soon as they reach the lungs, they begin to branch off, like the roots of a tree, so as to permeate every part of the lungs. These are called bronchi, or bronchial tubes. They ramify into an innumerable multitude of twigs, and terminate in the air cells of the lungs.

169. *Course of the air in breathing.*—We can now understand the course of the air in breathing. The air is admitted either by the mouth or nose. It enters the windpipe, proceeds to the forks of the pipe, enters the two bronchial tubes, proceeds to the lungs, and there, by means of the infinite branches of the bronchial tubes, reaches the air cells of the lungs and expands them. Having done its appointed work, the air returns by the way it came.

170. *Adaptations of the breathing organs.*—We shall find, on examination, each organ contributing to the process of respiration wonderfully adapted to its work, and all related to each other, and to the whole, so as perfectly to accomplish the design intended by the great, and wise, and good Author of nature.

We may first call attention to the fact, that there are furnished to animals two modes of admitting air to the throat—one by the mouth, and the other by the nose. There might not, at first, seem any design in this. But let us consider that if air had been admitted only by the mouth, which seems the natural inlet, (1) the young of animals could not breathe while sucking, and (2) the nostrils would have been nearly useless for the purpose of smelling. Odors could not affect the nose except through the medium of air. Air might, indeed, have been admitted to the lungs by an aperture in the chest; but then we must have lost many advantages.

171. *Special adaptations of the trachea.*—On examining the trachea, or windpipe, there will appear several points of interest, exhibiting special provisions for adapting it to the office it has to fulfill—the introduction of air to the chest.

(1.) There is a curious provision to prevent the admission of food. The passage from the mouth to the stomach lies along side of that to the lungs. The openings from the mouth to these two passages lie close together. The

entrance to the stomach lies behind that to the lungs, so that the food has to pass over the entrance to the trachea. Now, were it not for a special contrivance, there would be great difficulty in preventing the food, especially liquids, from going down the trachea.

This contrivance consists of a lid, or flap, accurately fitted, like a trap-door, to the orifice of the windpipe. We have alluded to this in section 122. The very muscular contraction, by which we perform the act of swallowing presses down the lid, so as effectually to close the passage to the lungs. As soon as the swallowing is accomplished, the muscles relax, and the lid flies open by a cartilaginous spring, so as to admit the air freely.

(2.) The windpipe is composed (§167) of cartilaginous rings. There is no other conduit of the body possessing this structure. And for this peculiar structure there are peculiar reasons. It was necessary, for the easy performance of respiration, that the windpipe should be always open. Were it liable to collapse, or close when empty, the passage of the air might be obstructed. Had not the windpipe been capable of sustaining a good degree of pressure, its sides might have been compressed by the external air, when that within became rarefied, and thus suffocation might have resulted. Its walls, therefore, are made firm and stiff, so as always to maintain their place.

(3.) The cartilaginous rings are not complete, being only in front and on the sides, and ceasing behind, where the trachea comes in contact with the passage to the stomach. This is designed to allow the esophagus, as the passage to the stomach is called, to distend when large pieces of solid food are swallowed.

(4.) The trachea is exquisitely sensible to every thing but air. Crumbs of food or drops of liquid, entering it by accident, produce violent and spasmodic coughing. Yet air passes in and out freely without any such effect.

Here are two inconsistent properties possessed by one and the same organ—sensibility and insensibility. Now, no reason can be assigned, why the windpipe should be insensible to the presence of air, but exquisitely sensible to the presence of every thing else, except that the Creator made it for the passage of air, and endowed it for our convenience with indifference to the presence of air, but at the same time endowed it, for our safety, with sensibility to the presence of every thing which might interfere with the process of respiration, thereby securing the violent expulsion of every dangerous substance from the lungs.

(5.) During the expulsion of the air from the lungs the capacity or calibre of the trachea is diminished. This increases the velocity of the ascending current of air. By this means any foreign substance lodged in the windpipe may often be expelled simply by breathing.

172. *Adaptations of the lungs.*—The design of the lungs is to establish a surface of contact between the blood and the air. Every particle of blood in the body must be submitted, in the course of a very few minutes, to contact with the air. At each pulsation all the blood sent to the lungs must meet the air in very small particles. Absolute contact, however, is not necessary. There is always a thin membrane between the blood and the air in the lungs. But animal membranes are permeable by air. Therefore, when the blood and the air in the lungs are separated only by the membranes, the contact is sufficient for all purposes, as the gases easily pass through the substance of the membrane, though the blood, from its greater consistency, cannot pass. The lungs, therefore, should be so constructed as to present as great a surface of contact between the blood and the air as possible. Let us see how this is done.

The lungs consist of two elements or constituent parts. These are the ramifications, or branching of the bronchial tubes, and of the blood-vessels. The tubes open to the air—

the blood-vessels to the heart. The tubes, as we have seen, (§168,) divide into branches so small as to be scarcely perceptible, and terminate in air cells. The blood-vessels likewise divide to imperceptible capillaries, and terminate in blood cells. There is only a slight membranous partition between the blood cell and the air cell. The same wall answers for both. On one side of the partition is the blood in its little cell; on the other side is the air in its little cell. The partition forms no impediment to the action of the air on the blood.

We are aware that in using the term cells in this explanation our language may not be absolutely correct; for so minute are both the blood and the air vessels in the lungs as to be hardly distinguishable by the most powerful microscope; and hence they are hardly large enough to be called cells. But the language we have employed is more intelligible than any other we can conveniently use.

If a problem to get the greatest possible surface in the smallest space were presented to be wrought out, I know of no solution equal to that presented in the structure of the blood and air vessels of the lungs.

173. *Course of the blood in the lungs.*—The blood, returning from the general circulation by the veins to the right auricle of the heart, is propelled to the corresponding ventricle, and from thence sent into the pulmonary artery. This artery, arising from the right ventricle, after proceeding a short distance from the heart, divides into two branches, one going to each of the lungs. Each branch accompanies the corresponding branch of the trachea in its bronchial ramifications. The blood thus is carried through all parts of the lungs by the capillaries and air cells, and then returns back to the heart through the pulmonary vein.

174. *Change of blood in the lungs.*—When the blood enters the lungs it is of a dark purple color, and is not only totally unfit for the nourishment of the body, but

actually poisonous. After being dispersed in most minute divisions in the lungs, and exposed to the air, particle by particle, it comes out a bright red color, purified of its poisonous properties, and rendered fit for re-circulation over the body. In a word, the blood is changed in the lungs from venous to arterial. It thus is prepared to go again its round, from the left auricle of the heart to the left ventricle, which opens its bosom to receive it, and then, by a powerful contraction, propels it to the capillaries, where it again loses its bright vermilion color, and becomes loaded with carbon or carbonic acid. It then is collected by the veins, returned to the heart, sent again to the lungs, renewed, and sent again over the body. Thus, by respiration, the blood is subjected to a constantly-reiterated change.

175. *Changes of the air in the lungs.*—The effects of respiration on the blood will be more clearly understood by examining its effects on the air.

The air, as we have before explained, (§15,) is not a simple, but a compound body, consisting of two gases, oxygen and nitrogen, mingled together much like milk and water. The oxygen is the only part used in respiration. The nitrogen serves only to dilute or weaken the oxygen, which alone would be too strong, and would excite the lungs to feverish action.

If you had to feed an infant on milk, it might not do so well to give it cream, but you might dilute the cream with water, making one-fifth only cream and four-fifths water. In this case the cream only nourishes the child, but the water answers the purpose of preventing the ill effects of a too rich and exciting diet. There is this difference in the application of our illustration. The milk and water are both retained in the stomach, though only the milk goes into the chyle. In breathing the oxygen only is retained by the lungs, the nitrogen being nearly, if not quite, all returned to the atmosphere. The air returned from the

lungs, after being once breathed, is found to have lost nearly all its oxygen, retained nearly all its nitrogen, and to have acquired a new gas called carbonic acid. It should be remarked, that the air when received into the lungs always contains a very small quantity, about a thousandth part, of carbonic acid. But that returned from the lungs contains a much larger proportion, corresponding generally to the amount of oxygen which has disappeared.

176. *Nature of carbonic acid.*—This gas consists of oxygen combined with carbon. It is always produced when wood, coal, oil, tallow, or any other substance containing carbon is burned. You may feel its influence by holding your head over a pan of burning coals. It is not the smoke of burning coal, but an invisible gas, which you could not, but for its effects, distinguish from pure air. It is fatal to breathe it for any considerable time. An animal confined in it soon dies. In becoming carbonic acid, carbon, at the moment of union with oxygen, changes its form from a solid to a gas.

177. *Origin of the carbonic acid expelled from the lungs.*—We have seen (§164) that there exists in the body a superabundance of carbon, which might be hurtful if allowed to remain. We have also seen (§175) that a large quantity of carbonic acid is thrown out of the body from the lungs; and we know of no means of getting rid of carbon other than combining it with oxygen, thereby forming carbonic acid. It is evident, therefore, that the oxygen of the atmosphere unites, somewhere in the system, with the carbon of the body. But it is not known whether this union is effected in the lungs or the capillaries. Some suppose that the union is effected in the lungs. The process would be as follows: the carbon is secreted from the blood in the capillaries, and sent forward in the veins to the heart, giving the blood its dark color. On arriving at the lungs, the oxygen of the air combines with the carbon of the blood,

forming carbonic acid in the lungs, to be immediately thrown out. According to this theory the blood takes nothing from the air. It only gives up its carbon to it. The change of color, from dark to bright red, is owing merely to the loss of carbon. Others suppose that the union is effected in the capillaries, by the following process: the blood in the lungs derives oxygen from the air, absorbs it, and carries it to the capillaries. In the capillaries the oxygen of the blood combines with carbon derived from the decaying tissues of the body, forming carbonic acid. This carbonic acid then is sent on to the lungs, where it passes through the membranous partition between the blood cells and air cells, (§172,) and passes out with the breath. At the same time all the oxygen of the air passes from the air cells to the blood cells, and combines with the blood. On the first theory the blood takes nothing from the air in the lungs, but only gives up its carbon. On the second, it gives up its carbonic acid, and receives in return oxygen.

178. *Conditions of healthy respiration.*—There are two conditions of healthy respiration: free action of the lungs, and full supply of air.

179. *Free action of the lungs.*—As the blood must be purified in the lungs, these organs are made of great expansive power, in order to afford as much space as possible for the contact of the blood with the air. Their full, free, easy, and unobstructed action becomes, therefore, indispensable to healthy respiration. There are, however, several ways in which the action of the lungs may be rendered deficient.

180. *Constitutional deformity.*—Some persons are born with narrow, badly-formed chests. Such constitutional defects are generally hereditary, and are transmitted from one generation to another, until the family becomes extinct, through the ravages of pulmonary consumption. Yet, judicious and regular exercise may do much to lessen, and, in many cases, may wholly remove these defects.

181. *Positions of the body.*—All unnatural and cramped positions prevent expansion of the lungs; and if continued for a long time, and frequently repeated, they may produce disease and death. Many persons in reading and studying, and especially in writing, lean forward in the chairs and press their chest against the bench or table. This produces serious injury, and often compels the student to relinquish his studies; whereas, the whole difficulty might be avoided by accustoming himself to sit up erect, and bring the chest out full, at some distance from the table. In sitting at our ease in a chair we are often bent forward, so as to confine the abdomen between the thorax and the thighs, thus preventing the contraction of the diaphragm, and seriously obstructing respiration.

Nearly allied to the last suggestion is one relating to our posture at church. We frequently sit with our heads leaning forward on the next seat, or our bodies doubled up, or kneel in an awkward and inconvenient position. We should, whether kneeling, standing, or sitting in public worship, remain upright in body as well as in mind.

But the most general and fatal method of cramping the lungs, and preventing their free action, is the ill-advised and suicidal mode in which many persons dress. No garment should ever be worn by man, woman, or child, so tightly-fitting, or closely-buttoned or laced, as to be felt in breathing, or as in the least to impede the full expansion of the chest. The mere weight of a garment is quite as much as any one can safely bear on his chest.

182. *How the expansibility of the lungs may be increased.*—The expansive power of the lungs may be increased by exercise, moderate running, reading aloud, speaking, and singing. Children should be allowed to halloo to their heart's content. Let them romp, and climb about, and make a noise. It is necessary to their health.

We see by these considerations that God, in his wisdom

and goodness, has provided the means by which we may supply defects in our physical organization, and avoid the evils of injudicious habits. If we suffer from defective lungs, let us not, therefore, blame Providence, but ourselves; for he has given us the means of correcting these defects.

183. *Supply of fresh air.*—The second condition of healthy respiration is a good supply of fresh air. We have already (§15 and §175) described the physical properties of air, and seen that it is composed of oxygen and nitrogen. The oxygen is the vital part, and the nitrogen merely a diluent. When we inhale a breath of air, the oxygen is nearly all absorbed, while the nitrogen, with a small portion of carbonic acid, is returned. From this fact you may easily perceive what happens when you breathe the confined air, like that of a close room. The oxygen is soon consumed, the nitrogen cannot support life, and the carbonic acid is positively injurious. If, therefore, a single person were confined to a room so close as to admit of no ventilation, expelling the bad and admitting the good air, he would soon die. All have heard of the horrible fate of the one hundred and forty-six Englishmen, who were shut up in the Black Hole of Calcutta. They were all thrust into a confined space, only eighteen feet square. At the end of six hours ninety-six of the poor prisoners were dead. Those who survived never recovered from the poisonous effects of vitiated air.

Many of our churches, especially in the west, are but little better than the Calcutta Black Hole. They are small, very low in the ceiling, and poorly supplied with windows and doors. In these the people are packed close as a box of herrings, till they ferment and putrefy. In our small towns the same room is generally used for preaching in the morning, Sabbath school in the afternoon, and preaching again at night. It is no wonder the people get sleepy in such houses. Instead of lecturing the people on sleeping

in church, the preacher should instruct the sexton on ventilating the house.

Our school-houses are generally worse than our churches. Fifty, sixty, and sometimes a hundred children are confined for six hours or more in a close, hot, seven-by-nine room, affording hardly air enough for a good-sized grasshopper. Neither parents nor teachers appear to be aware of the sufferings endured, or the dangers incurred.

Our bedrooms are frequently the smallest and worst-ventilated rooms in the house, whereas they should be the largest and most airy. There is no need of our ever suffering from a deficient supply of air. God has made an atmosphere more than forty miles high, and extending all over the earth, and it costs nothing to use it. If we suffer from a scanty supply, it is our own fault.

184. *Carbonic acid*.—We have already remarked (§175) that a small quantity of carbonic acid is thrown from the lungs in respiration. It seems to be formed in the process of breathing. It is also generated by many natural processes, and, in some situations, exists in considerable quantities. It is heavier than air, and, therefore, sinks to the bottom of wells, and caves, and low valleys. It is often produced in rooms by pans of burning coals, designed to warm sleeping-rooms, in which no fire is kept. It is fatal to animal life, and deplorable accidents often happen from it, which might be prevented by science and care.

185. *Malaria*.—This name is often applied to the noxious gases existing in the air about low, marshy places. In warm climates the vegetation, usually rank about marshy places, rapidly decomposes, and the gases thence arising mingle with the atmosphere, and become the fruitful source of diseases. During the day, it being rarefied by heat, malaria rises to the upper regions of the atmosphere. At night, becoming condensed, it falls near the earth. It seems not, however, to settle in the lower valleys, but gathers

about the bluffs and lands of medium height. It is found, therefore, by experience, particularly in the west, that a position on the bottom lands, nearly on a level with the river or marsh, is less unhealthy than on a neighboring bluff. It is found that a house located at the head of a ravine, is peculiarly exposed to malaria. The evils of malaria may be greatly lessened, if not wholly avoided, by prudence and care. Expose not yourself to out-door night air, and kindle a fire in your room at night, so as to keep the temperature of the night and the day nearly equal, and accustom yourself to cleanliness and the wearing of flannel, so as to keep up a healthy condition of the skin, and you need fear little from miasmatic influences.

186. *Local causes of bad air.*—There are frequently causes of bad air about our own houses and inclosures. They might be easily removed, but ignorance or idleness suffer them to remain. Vegetables are left to decay in the cellar. Manure is left, through the long, hot summer, to ferment in the barn-yard. Dead animals are left to putrefy on the grounds, and poison the atmosphere. Every thing of this kind should be buried in the ground. No malaria will arise from filth covered up with soil. It is when exposed to the air and sun that it does so much damage. The application of lime about places affected with disagreeable gases, will prove very serviceable.

Pools of stagnant water are often permitted to lie, and sweat, and broil, and grow green in the sun, and fill the air with noxious vapors, while a few hours of labor might drain them all off. Neglect of these small matters is bad economy. It costs a great deal to be sick. It is much cheaper to be at a little expense in removing and avoiding causes of disease.

187. *Cause of death by suffocation.*—The exclusion of air from the lungs for any considerable time, results in death. There are several means by which suffocation may be pro-

duced, such as the accumulation of fluids in the chest, so as to prevent the expansion of the lungs; the lodging of foreign bodies at the orifice of the throat; hanging; exposure to carbonic acid, and drowning. Carbonic acid and water seem to operate in the same way. The entrance to the windpipe is endowed with a remarkable irritability, whereby, on the contact of all solids and fluids, and all gaseous substances, except atmospheric air and the respirable gases, it is instantly closed. When, therefore, we are exposed to carbonic acid, or water, the passage by which air enters the lungs suffers a spasmodic closure.

The blood, unpurified, goes again the round from whence it has returned, but in a condition not only unfit to support the body, but actually poisonous. It paralyzes the capillaries, deadens the brain and nervous system, and destroys life. Breathing can be suspended for only a few minutes without destroying life, unless circulation cease at the same time. But if circulation be nearly or quite suspended, as is generally the case in fainting, respiration may also be suspended for a long time without danger. Cases of suspended animation sometimes occur. In these cases, respiration and circulation stop at the same moment. The patient may appear dead, preparations may be made for the funeral, and yet restoration may occur. It is even probable some persons have been buried, while yet life was only suspended, and might, by proper means, have been restored.

188. *Relations between respiration and circulation.*—The wisdom of Providence is seen more clearly in nothing than in the relations often discovered between different functions. The relation of frequency between respiration and pulsation is remarkable. When, by running, or other violent exercise, we produce rapid circulation, the breathing involuntarily becomes hurried. While we sleep, both functions are retarded. In diseases acceleratnig the circulation, respiration

also becomes hurried. In childhood both functions are performed more rapidly than in mature life, and in old age both are equally retarded. Were it otherwise—did not respiration always keep pace with circulation, varying in frequency according to conditions of health and disease, youth and old age—serious mischief would result. Unpurified blood would circulate through the system, carrying poison, paralysis, and death all along its course.

189. *Modifications of the respiratory organs.*—The respiratory organs of each living being are modified to suit its natural condition. Vegetables breathe by means of their leaves. Fishes breathe by their gills. These organs are not adapted to air; and therefore fish cannot live on land. Their gills, however, are adapted to breathing the air absorbed by the water. Fish cannot live in boiled water, because the air is boiled out. Nor can they live long in a pond entirely frozen over, because the small quantity of air contained in the water would soon be used up, and the ice preventing a re-supply from the atmosphere, the fish would suffocate. If a pond containing fish be frozen over, and you cut a hole in the ice, the fish will rush to the opening so greedy for air, that you may catch them by your hands.

Many species of insects and worms breathe by means of openings in their backs, admitting the air to their blood. You may satisfy yourself of this fact by besmearing the insect with oil, so as to block up the openings. The creature will soon die for want of breath.

190. *Torpidity.*—In animals lying torpid during the winter there appears a wonderful relation between the circulation, respiration, and nourishment. Generally, animals require daily food. While circulation is going on with its usual rapidity, no animal can live many days without food. But, in a torpid state, they may remain in tolerable condition for months, and some are supposed to live for years without any thing to eat. In this condition animals are

said, in popular language, to live upon their fat; nor is the expression incorrect. There is, in animal organization, a tissue, called the cellular tissue—the cells filled with fat, or oil, called adipose matter. When there is much of this adipose substance in the body, the cellular membrane occupies all the valleys between the muscular ridges, and gives the body a full, plump, and rounded appearance. The animal is then said to be fat. If, by want of food, or by disease impairing digestion, the system be not furnished with its accustomed and necessary nutriment, the animal is supported by the adipose matter. When this is used up, the animal is said to be poor, or lean. It is this that supports animals during their torpidity. In order, however, that the quantity of adipose laid in at autumn may serve till spring, the circulation, by means of which the nutriment is distributed, goes on very slowly. In some animals the pulsations are reduced from one hundred and fifty a minute to only fifteen. Digestion ceases entirely, the only nourishment being derived from the animal's own fat. Respiration still keeps pace with circulation; and thus a triple relation between nourishment, circulation, and respiration is kept up. It is a curious fact that torpidity, which seems required of animals, owing to the impossibility of their obtaining a supply of food in winter, is brought on by the very influence which exhausts their resources for food. Cold weather at once produces the torpid state. Reptiles soon fall into a torpid state, when the thermometer falls below fifty degrees. By putting them in an ice house, in which the temperature remains below that point, they have been kept in a torpid state for three years and a half, and then revived.

It is a remarkable fact that, while the ordinary cold of the season keeps animals in a torpid state, exposure to severe cold—such as might endanger life—rouses them. Thus the same agent, in moderate action, promotes torpidity, but, in excessive and dangerous action, rouses from it.

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Were it otherwise, the life of these animals might be destroyed, by unusual cold, or by accidental exposure of their habitations to the access of cold. Benevolence and wisdom are seen in this remarkable provision.

LECTURE IX.

THE TEMPERATURE, COVERING, MOTIONS, FOOD, AND TRANSFORMATIONS OF ANIMALS.

Animal heat—The living body a generator of heat—How we make heat—Influence of climate on the generation of animal heat—Influence of food on the production of animal heat—Influence of exercise on animal heat—External protection of organic beings—The skin—Structure of the skin—Use of the epidermis—Beneficent provisions—Structure and use of the second coat—Structure of the third coat—Uses of the skin—Covering of animals—Adaptation to the elements—Adaptation to climate—Adaptation to the season—Special provisions—Motions of animals—Relation of organs of motion to the element and mode of being—Food of animals—Variety of food—The existence of carnivorous animals consistent with the divine benevolence—Transformation of animals—Design of transformation—Death of animals.

191. *Animal heat.*—It is well known that all living beings maintain a temperature of their own, independent of surrounding media. The temperature of one species, or order, of animal varies from that of another species, and the temperature of a particular individual may slightly vary from that of another individual of the same species; but the temperature of the same individual never varies perceptibly, unless affected by disease. It is true, the surface of our body may become chilled in winter and burnt in summer; but the general temperature of the body, as indicated by a thermometer placed in the mouth, or any other internal cavity, would be found the same in summer and in winter—in Greenland and in Georgia. Men have been exposed to a temperature of fifty degrees below and two hundred and fifty degrees above zero, making a difference of three hundred degrees, and yet the temperature of their bodies would not vary two degrees.

192. *The living body a generator of heat.*—It is one of the laws of heat to diffuse itself equally among all bodies within the sphere of its influence; so that, if bodies une

qually heated be brought near each other, the warmer will impart heat to the colder, until all become of the same temperature. Living bodies form no exception to this law, for they impart heat to bodies colder, and receive it from those warmer than themselves, in the same manner as inorganic bodies.

The human body is usually of a much higher temperature than the surrounding atmosphere. The general temperature of the body is about ninety-eight degrees. Dr. J. Davy, from late observations, estimates it higher, fixing the mean, or average, at one hundred degrees. Very seldom, in any latitude inhabited by man, does the thermometer rise in the air above that point. There is scarcely a day, in the hottest of summer, when, in this latitude, the temperature is so high as one hundred degrees. It will appear, therefore, that, during far the greater part of the year, the temperature of our body is far above that of the atmosphere in which we live; and, therefore, by the laws of radiation, conduction, and distribution, we are constantly throwing off heat to surrounding bodies; yet we keep our own temperature up. Where do we obtain our heat? We *make it*.

193. *How we make heat.*—By what constitution of our nature—by what vital process we manufacture animal heat—is an interesting question, but one not easy of solution. There is evidence that it is connected, in some way, with respiration. Animal heat is found to exist in proportion to the energy and efficiency with which respiration is conducted. Amphibious animals and fishes, whose respiration is defective, have so little heat that they are called cold-blooded. Birds, whose respiration is more vigorous than that of man, have a temperature several degrees higher than he ever attains. Diseases that diminish respiration produce coldness of body, while those that increase the rapidity of breathing produce fever. All exercises increasing frequency of res-

piration, increase, also, the heat of the body. There is, therefore, most obviously, a relation between circulation, respiration, and animal heat; but the links forming the connection are not yet clearly defined.

You will find, in most books of chemistry, the origin of animal heat ascribed to a process of combustion. We know that the union between oxygen and carbon, in the burning of wood, and coal, and oil, and tallow, does produce heat. We know, also, that carbon and oxygen do unite in the human body, either in the lungs or capillaries, and that the same product is evolved by this union, as by ordinary combustion. This product, in both cases, is carbonic acid. As, therefore, the combination of oxygen with carbon out of the body produces heat, it may be reasonably inferred, that the combination of the same elements in the body may have the same effect. There are, however, difficulties and objections in the details of this theory. Enough only is known to show, that the indirect and apparently-inconvenient mode of getting rid of the superabundant carbon in the body, which we have described in our lecture on respiration, was adopted, as we have hinted in section 164, for the purpose of securing the uniform temperature most conducive to the due performance of the functions of animal life.

194. *Influence of climate on the generation of animal heat.*—Far more heat must be given off from the body to the atmosphere in a cold than in a warm climate, and in winter than in summer. Yet the body remains of the same temperature, in all climates and at all seasons. There must, therefore, be generated more heat in cold than in warm atmospheres. And what is evidence of divine wisdom, the animal system is found, by experiment, to be constituted capable of producing heat in proportion to the climate and season. The same cause, therefore—cold weather—which requires the production of great animal heat, also furnishes the stimulus for generating it.

195. *Influence of food on the production of animal heat.*—

If, as is probable, animal heat be the result of the combination of oxygen with carbon in the body, then the amount of heat generated will depend on the amount of carbon in the system. But the amount of carbon depends on the amount and quality of the food. All food of an oily character contains large quantities of carbon. Fat meat and lard are nearly all carbon. The more exclusively we live on animal food, the more heat we are capable of producing. Now, it is a curious fact, that the inhabitants of cold climates, where much animal heat is demanded, are obliged, from other causes than this demand, to subsist on animal food. Vegetable food, suitable for man, cannot be obtained in high latitudes. And if it could be obtained, it would not so well answer the purposes of human life. Animal food, the only kind suited to the necessities of the inhabitants of cold climates, is abundantly furnished, and the only kind that is furnished. We see herein admirable relations between the climate, the amount of heat demanded by it, the kind of food furnished, and the adaptedness of that species of food to produce the heat.

196. *Influence of exercise on animal heat.*—The well-known influence of exercise on the production of animal heat, furnishes us another interesting series of relations. The inhabitants of tropical climates need little exercise to promote health. Their bodies generate, without the exciting stimulus of active labor, sufficient heat for the purposes of health. Nor are they obliged to labor for the procuring of food. The earth produces spontaneously sufficient food for the supply of their wants. But in cold climates exercise is necessary to keep up heat, so as to preserve health, and is, also, imperiously demanded for obtaining sustenance. We see, therefore, that we are obliged, for the supply of our wants, to put forth the exertion necessary for the preservation of health. Were food as easily procured in cold

as in warm latitudes, men would not take the exercise demanded by their circumstances. On the other hand, were food as laboriously obtained in the tropical as in the temperate and frigid zones, the inhabitants would suffer by excessive exercise, producing excessive animal heat.

There would seem no necessary connection between things so dissimilar as climate, food, exercise, and animal heat. But God, in his wisdom, has joined them all by curious and dependent relations. None but a Being of infinite knowledge, and superintending all things, could so adjust complicated relations between things distinct and apparently independent.

197. *External protection of organic beings.*—All living beings, from the most ordinary weed up to man, are furnished by the all-wise and benevolent Creator with an external covering, protecting the delicate structure of the organized fabric from the injurious influence of external agents. Vegetables of every order and species are furnished with bark, and animals with skin. The resemblance between bark and skin, in their structure and uses, is very close. However great may be the diversity in the form and outward appearance of the bark of vegetables and trees, and the skin of insects, fishes, birds, beasts, and men, yet it is easy to discover, amidst all the varieties, that the same general plan has been followed in the construction of the integuments of all living beings, and that each particular formation is the result of a combination of the same elementary structures.

198. *The skin.*—As the discussion of all the varieties of integument would carry us through too wide a range, we will confine our remarks principally to the structure and uses of the human skin.

The skin invests the entire body, without and within. Every cavity of the body is lined with it. The same skin which covers the face, is continued over the lips into the

mouth, down the windpipe, and down the throat, and through the stomach and intestines. The line of division between the external and internal skin, is marked by a slight difference in appearance, but the structure of both is the same. Should any portion of the external skin become turned in, it would soon assume all the appearance of the internal. And should the internal become exposed to the outward atmosphere, it would, also, assume the appearance of the external. To distinguish, in one word, the internal from the external skin, physiologists call the former mucous membrane. But the distinction is not an organic, but a local one.

199. *Structure of the skin.*—The skin consists of three coats. The outer is called the epidermis, or cuticle, or scarf skin. It is known by each of these terms indiscriminately. It is transparent, and destitute of sensibility. The second, or middle coat, is called the rete mucosum, or mucous net-work. It is the seat of the coloring matter, giving all the varieties of complexion to the human race. The third coat is called the chorion, and sometimes the dermis, cutis, or true skin. This coat is delicately organized, and sensible to a very high degree.

200. *Use of the epidermis.*—The scarf-skin is designed, (1.) To protect the exquisitely-sensitive true skin from irritation. Were the true skin exposed to constant contact with external nature, violent inflammation, causing death in a short time, would be inevitable. The scarf-skin is wholly insensible, as may be seen by experimenting on it, when raised by a blister. Its insensibility adapts it to its exposed condition, as it may endure the roughest treatment without causing pain. In section 43 we maintained that pain is a special endowment to particular organs of animal nature, to warn against injury. The scarf-skin, though more exposed than any other organ of the body, is yet wholly insensible to pain. Is this fact consistent with the doctrine

of section 43? It is; for it is remarkable that the scarf-skin has neither blood-vessels nor nerves, and can hardly be said to be an organized substance. It seems to be a deposit of animal matter, much like the shell of a lobster. Tearing or removing it would affect us only in the same way as rending or removing our clothing. It would simply be taking away our means of defense against external impressions. No injury would directly result to the organized system by removing the whole at once. Serpents and lobsters do shed theirs without injury, and with only temporary inconvenience.

(2.) The scarf-skin prevents too rapid perspiration from within, and absorption from without. When the atmosphere is dry, there is tendency to excessive perspiration. When it is moist, there is danger of injurious absorption. Were it not for the scarf-skin, we should be at the mercy of every change in the weather. Life would be destroyed, either by exhaustion from the loss of fluids, or by poisonous gases and malaria, readily admitted to the body from every part of its surface. Were it not for our protection by the epidermis against absorption, many of the most valuable trades, now safely followed, would have to be abandoned. We could not work among paints and poisons, and fumes and gases, without certain death. Protected by the scarf-skin, we may handle poisons with safety. But without it, we could not long live surrounded by deleterious effluvia and malaria.

201. *Beneficent provisions.*—There are in the cuticle several modifications, exhibiting benevolent design, too interesting to be passed over in silence.

(1.) In the palms of the hands and soles of the feet, the scarf-skin is naturally thicker than in less exposed parts of the body. The difference is perceptible even at birth, before using the part can have exercised any influence. The obvious design of this modification, is to afford additional protection to the parts most exposed.

(2.) Though the cuticle is nearly destitute of organization, yet it is capable of assuming such changes in structure on particular individuals and particular parts, as circumstances may require. By use it may grow thicker and thicker, until it becomes hard as horn. Were it not for this provision, the blacksmith, the mason, the stone-hammerer, and the farmer could not ply their trades without the constantly recurring of that painful blistering which the young apprentice has to undergo.

(3.) At the ends of the fingers and the toes the skin becomes nails. Nails are identical in organization with the scarf-skin. They properly form a part of it, and answer the same purpose of protection, being modified in form and structure to suit their local position. But why should the scarf-skin, which invests all the body, be of uniform texture and appearance over the greater portion of the fabric, yet in the palms of the hands become thicker, and at the extremities of the fingers become nails?

There is manifest design in the matter. Were the skin formed by any necessary law, it would be of uniform texture throughout. Were the substitution of nails for skin accidental, the nails might be scattered at random over the body. The will of God alone is the cause of this peculiar modification. No man can assign any efficient reason, in the nature or necessity of things, why nails should be formed at all, and, if at all, why they should be found at the ends of the fingers. The convenience of man requires them there, and therefore God put them there.

202. *Structure and use of the second coat.*—This coat is a thin, soft covering, destitute of blood-vessels and nerves, placed between the outer and inner skin. It probably serves some purpose of protection to the nerves and blood-vessels of the true skin. But its principal use seems to consist in affording, by its coloring matter, variety and beauty to the bodies of men and animals. To it the dolphin and salmon

owe the exquisite beauty of their colors. All the varieties of complexion and color among the races and individuals of men depend on the modifications in amount and quality of the pigment of the rete mucosum.

Nor is it unreasonable to regard beauty alone as one of the prominent designs of God in the constitution of nature. He has spread before the eye of man scenes of beauty everywhere. There is beauty on earth, beauty in the heavens, and beauty in the waters. Tinged with beauty of color are the clouds of the sky, the leaves of the trees, the flowers of earth, the plumage of bird, the wings of insect, and the skin of animal.

203. *Structure of the third coat.*—The true skin is very delicately organized, of great firmness and power of resistance, extensible and elastic, crowded with nerves and blood-vessels, and endowed with sensibility to a very high degree.

204. *Uses of the skin.*—The uses of the skin are various and important. Of them we will only notice the following:

(1.) The skin serves as an exhalant of waste matter from the system.

We have seen, in the lecture on digestion, that food is separated in the stomach and intestines into two parts—the one entering the blood for nourishment; the other thrown out as useless, or injurious. In perfect health the digestive apparatus is sufficient to separate and expel the useless portion of the food. But when the digestive organs become affected with diseases, to which they are peculiarly liable, injurious matter from the food will enter the blood, and in that case the skin furnishes the only chance of riddance. Again: in section 36 we explained the process of decay constantly going on in the system, and showed how the lymphatics carry away the old and decaying matter, and pour it into the thoracic duct with the blood. Lymph must contain deleterious particles. As these cannot pass off

with the feces, as they never enter the digestive cavities, their only chance of escaping is by the skin.

To perform the laborious duties of exhalation the skin must be constantly active. Not only when in a high temperature we suddenly break out into profuse perspiration, but at all times, by an insensible yet efficient perspiration, are we throwing off, by the skin, useless and deleterious matter from the body.

Slight obstruction of this insensible perspiration causes disease, and total obstruction results in death. Nor will the fatal effects of total obstruction appear strange, when we learn what a large amount of matter the skin has to throw off from the body. According to experiments made by Lavoisier and others, it appears that, on the lowest estimate, twenty ounces of waste matter is thrown out by the skin every day. More is probably effected in this way by the skin than by both the kidneys and bowels.

The skin is wisely adapted to the performance of this work. Its extent presents an immense surface, and its structure consists of an accumulated mass of nerves and blood-vessels. By far more blood flows through the skin than through any other equal portion of matter in the body. The scarf-skin, while it prevents too rapid exhalation, does not interfere with a healthy degree, it being easily permeable through its pores to the natural perspirable matter.

(2.) In section 192 we noticed the amount of heat which animals are capable of generating. Were it to accumulate on the body it would produce death. But accumulation is prevented by several causes, among which evaporation from the skin is the most important. Under the influence of high temperature, or active exercise, profuse perspiration bursting out carries off by evaporation the surplus heat, and leaves the body cool and comfortable. The matter exuded in this extraordinary perspiration is not altogether of injurious nature, but is furnished mostly from liquids taken into

the stomach. A fresh supply of water, therefore, is frequently necessary to keep up the perspiration. And here we observe a relation between the *necessity* for water and the *desire* for it. Whenever we perspire freely we *must* drink to support the perspiration; and we *do* drink, because we are thirsty. I know not as there is any necessary connection between the demand caused by perspiration for water and our desire for it at that particular time; yet it hath pleased God that whenever, by excessive perspiration, water becomes indispensable to health and safety, we should be impelled by thirst to drink it.

In section 131 we suggested that hunger and thirst were probably specific endowments of the digestive organs. Their action is intermittent, and in health is exerted only when the condition of the body requires it. Great wisdom is exhibited in adjusting the periods and extent of their action to the varying demands of the system.

(3.) In section 200 we alluded to the absorbing power of the skin. Substances applied to the surface may thus enter the circulation and be diffused through the system. Though it is undoubtedly possible to introduce sanitary substances into the system by absorption, yet it is seldom necessary to resort to this method; and the effects of absorption generally, so far as they are now understood, are injurious. Poisons applied to the surface may be absorbed, and produce death. Malaria is probably more frequently admitted to the system by the skin than by the lungs. The effects of absorption are especially injurious in warm, miasmatic, and damp localities. In a dry atmosphere exhalation counteracts absorption. But in a damp condition of atmosphere exhalation is suppressed, and absorption excited; and if poisonous gases and miasmatic effluvia be present, they are sure to find their way into the system, producing disease and death. The absorbing power of the skin may, however, be designed for some wise and benevolent purpose, not yet discovered.

When we cannot detect the benevolence of any natural law, it is wise in us to make, in our conclusion, allowance for our own ignorance, before we impute to the wise and good Being either lack of wisdom or want of love.

(4.) The skin is the seat of tactual sensation. For this purpose it is furnished with a wonderful supply of nerves. Those parts designed as special instruments of touch, as the tip of the tongue, and the ends of the fingers, are a perfect mass and net-work of nervous fibres. By means of this structure we acquire all our knowledge of forms and magnitudes.

205. *Covering of animals.*—Man, as Paley observes, is the only animal furnished with no natural covering. This is not a defect, but a wise provision. He may now, by artificial covering, adapt himself to any climate, from the equator to the poles. Among the various orders of living creatures, there is every possible diversity of covering, adapted to the element in which the animal lives, the climate to which he is subjected, and the circumstances by which he is surrounded.

206. *Adaptation to the elements.*—The adaptation of the covering of animals living in the water, in the air, and on the land, to the elements in which they live, must be obvious to every observer. What could be better adapted to the fish than scales? What more suitable covering for the bird than feathers, combining lightness, strength, and warmth? What more convenient clothing for the quadruped than the varieties of bristle, hair, and wool? Change the covering of the fish and the bird—give the former feathers and the latter scales—and to what an awkward predicament they would be mutually reduced!

207. *Adaptation to climate.*—It is well known that animals living in cold latitudes have a much thicker and warmer covering than those living in temperate regions. In the north the covering is fur, or thick wool. In the south it is

hair. So uniform is the law, that should there be found among fossil remains the covering of an unknown animal, it might be easily determined whether the creature lived in a cold or a warm climate. If it be said, though it cannot be proved, except by experiment, that high temperature has a tendency to thin out, and low temperatures to thicken up furs, still the indication of design is equally clear; for no reason can be given why cold should necessarily increase the quantity and fineness of fur. God pleased to order it so, and the design is as evident and as benevolent as if he effected the change by direct and immediate interposition of his almighty power.

208. *Adaptation to the season.*—The covering of animals is known to thicken up in winter. The skin of the beaver and of the hare is good for nothing for fur in summer. It is covered with thin, coarse hair. At the approach of winter a fine fur is produced, and remains till the approach of warm weather. The covering of some species changes, on the approach of winter, in color, from brown to white. Brown promotes and white retards the radiation of heat; and the design of the change is to keep the animal heat, during the cold weather, from escaping into the atmosphere.

209. *Special provisions.*—There are a few special provisions regarding covering worthy of notice.

Birds living in air or on land have the thickest and warmest covering on the back, while water fowl have it on the under surface. Hogs, whose bristles afford small protection against cold, find ample compensation in the mass of fat covering the body. The whale of the northern ocean is protected against the intense cold of the frozen seas by the amount of oily tissue beneath his skin. And thus, had we means of observation, and time to go into the investigation, we should find that every species of living creature is provided with such kind of covering as is best adapted to its wants and circumstances. Nothing is forgotten; nothing

neglected. The little sparrow claims and receives from its divine Creator the same care and protection afforded to the king of birds; nor is the most humble creature neglected, in the general distribution of the divine benevolence.

210. *Motions of animals.*—We have already described the bones, joints, and muscles, which furnish animals means of locomotion. There are, however, several wise provisions, exhibiting curious relations, which it may be interesting to notice.

211. *Relations of organs of motion to the element and mode of being.*—Every class of animals is furnished with instruments of motion adapted to its element and mode of being. Thus, quadrupeds move more easily on the ground, birds in the air, and fishes in the water. Change the element of being of any animal, and its organs of motion would be ill-suited to its new condition. Animals whose food is the fruits of trees are furnished with limbs peculiarly adapted to climbing. This is the case with monkeys and squirrels. The foot of the woodpecker is made on purpose for holding on to perpendicular trees. The crane has long legs, and the goose a web foot. The mole has a shovel-shaped foot. The camel and the polar bear have broad, flat feet—the one for traveling over sandy deserts, and the other for tramping in snow and ice.

The timid and persecuted classes of animals, such as the hare and deer, are extremely rapid in their motions; while the ferocious, strong, and cunning are slower. Insects, whose food has to be sought in a wide range, hum swiftly through the air; while those whose food is always at hand, move very slow. Fishes, whose motions in the water are horizontal, have a vertical fin at the tail; while those which have to come to the surface to breathe, as the whale and porpoise, have a horizontal fin, enabling them thereby to rise easily.

212. *Food of animals.*—Animals cannot live on inorganic

matter. The elementary substances of nature must be worked over, modified, and assimilated by vegetation, before they become suitable for animal sustenance. Even earth-worms live not on mineral matter, but on the vegetable mold in the ground. Mineral matter cannot be digested by animal organs. When, by accident or design, taken into the stomach, it operates either as a poison or medicine; but mineral and inorganic elements, becoming organized in vegetable products, acquire those properties which fit them to support the innumerable species of animal life.

213. *Variety of food.*—If all insects and herbivorous animals subsisted on any one species of plant, an adequate supply would be impossible. Many of the feebler species of animal would die with hunger. Should all carnivorous beings become addicted to the same kind of prey, the supply would soon fail. But the food of animals is as various as the species. There is not a plant—not one—which furnishes not the appropriate food of some insect or animal. Poisonous the plant may be to some species, but what is poison to one is meat to another.

Vegetables are not the only food of animals. From the ant to the lion, not excluding even man, they prey on each other. Many species of insect feed on other species, and all species are greedily devoured by birds. Birds, in their turn, become the prey of the carnivora of their own kind, or the food of man. The herbivorous beasts are constantly falling victims to the carnivorous. Nor is the carnage less incessant, nor the warfare less perpetual in the sea than on the land.

214. *The existence of carnivorous animals consistent with divine benevolence.*—It is not easy for him, who looks only to individual and not to general results in the economy of nature, to reconcile the existence of carnivorous beings with the divine benevolence; but the more enlarged view, while it regards individuals in their conjoint relations to the gen-

eral benefit of their own species, and that of other species with which they are associated, in the great family of nature, resolves each individual case of apparent evil into subserviency to the general good. The best view I have ever seen, on this subject, is given by Dr. Buckland, in his *Bridgewater Treatise*. I cannot do better than to transcribe, in nearly his own language, his remarks on this matter:

"The law of universal mortality being the established condition on which it has pleased the Creator to give being to every creature on earth, it is the dispensation of kindness to make the end of life to each individual as easy as possible. In inferior animals a sudden termination of existence is obviously most desirable. The pains of sickness and the decrepitude of age—the usual precursors of death—resulting from gradual decay, are in the human race alone susceptible of alleviation from internal sources of hope, and from the tender sympathies of humanity. Throughout the whole brute creation no such hopes exist—no such sympathies are manifested. There is no affection for the feeble and the aged—no relief to the sick—no consolation to the dying. The extension of life through lingering stages of decay and of old age would be, to each individual, a scene of protracted misery. Under such a system the natural world would present an amount of daily suffering bearing a large proportion to the total amount of animal enjoyment. By the existing dispensations of sudden destruction and rapid succession, the feeble and disabled are speedily relieved from suffering, and the world is at all times crowded with myriads of sentient and happy beings. Though to many individuals the allotted share of life is short, yet it is usually a period of uninterrupted gratification, and the momentary pain of sudden death is an evil small in comparison with the enjoyments of which it is the termination.

"Besides the desirable relief of speedy death, on the approach of debility or old age, the carnivora confer a fur-

ther benefit on the species which form their prey, by controlling their excessive increase. Without this salutary restraint, each species would soon multiply to an extent exceeding, in a fatal degree, their supply of food; and the whole class of herbivora would ever be so nearly on the verge of starvation, that multitudes would be daily consigned to lingering and painful death by famine. All these evils are superseded by the establishment of a controlling power in the carnivora, maintaining a due proportion of species, one to another, and consigning the sick, the lame, and the the aged to speedy death.

"The appointment of death by the agency of the carnivora, as the ordinary termination of animal existence, appears, therefore, in its main results, to be a dispensation of benevolence, deducting much from the aggregate amount of the pain of universal death, abridging greatly, throughout the brute creation, the miseries of disease and lingering decay, and imposing such salutary checks upon excessive increase of numbers, that the supply of food maintains perpetually a due ratio to the demand.

"The result is, that the surface of the land and the depths of the waters are crowded with myriads of animated beings, the pleasures of whose life are co-extensive with its duration. Life to each individual is a scene of continual feasting, in a region of plenty; and when unexpected death arrests its course, it repays with small interest the large debt which it has contracted to the common fund of animal nutrition, from whence the materials of its body have been derived. Thus the great drama of universal life is perpetually sustained; and, though the individual actors undergo continual change, the same parts are ever filled by another and another generation, renewing the face of the earth and the bosom of the deep with endless successions of life and happiness."

215. *Transformations of animals.*—We have remarked

(§19) on the incessant changes to which organic beings are, from their very constitution, subject. These changes, in some species of insect, result in curious transformations. It has long been known, and has always excited the admiration of mankind, that worms and caterpillars undergo, at certain periods of life, strange transformations—from creeping things to winged insects. No two things in nature can appear more unlike than a crawling, hairy, and disgusting caterpillar, and a flying, gayly-colored, beautiful butterfly; yet they are one and the same being, changed only in appearance, form, and mode of life. The transformation is but a particular result of the general law of change—a law extending over the whole range of animated nature. The change is but a progressive development, designed by the all-wise Creator, and provided for, in all its modifications, by the watchful care of Providence.

Scarcely less remarkable are the changes in vegetable than in insect life. The acorn incloses in its folds the germ of the oak. It needs only development to become the magnificent forest tree, giving comfort and repose to the weary traveler, and defying the winds and the storms of centuries.

Amphibious reptiles undergo changes, quite as remarkable as those of insects. The embryo frog is at first but an egg. Escaping from the egg, it is a tadpole, with a large, round head and flat tail, but destitute of feet and legs, and incapable of living out of the water. By gradual changes the tail disappears, the legs and feet protrude, and the creature comes out a quadruped, capable of motion and life on land as well as in water.

Birds change greatly in their progress from birth to maturity. The chicken differs greatly in appearance from the full-grown hen. The gosling and the goose would hardly be taken for the same species. And no one, on finding, for the first time, the young of the whippowil, as

it lies "squat, like a toad," on the crumbling remains of a rotten log, would think it possible that such a looking creature could ever become the interesting bird that sings at nightfall the plaintive lullaby to the drowsy ear of tired childhood.

Quadrupeds change. How different in outward appearance, and in disposition, the calf from the ox—the fawn from the deer!

Man, from his embryo state to his final dissolution, is passing through a continuous series of changes. In infancy he is toothless and beardless, his head is out of proportion, his limbs out of shape. In boyhood he becomes chubby and fair, his teeth being cut, and all his limbs advancing in size and symmetry. In manhood his form is fully developed, and he walks the earth a creature of beauty and of majesty, the lord of the creation. In age his form is bent, his teeth are gone, his steps tottering, his eye dim, and his natural strength abated.

In mind, as well as in body, incessant change passes over man. In infancy the intellectual and moral powers seem just waking from a sleep which has no beginning. In childhood the mind revels amidst rainbows and butterflies, chasing all day the shadows over the lea, and having no thought for the morrow. In manhood the mind assumes a bold, active, calculating cast. We engage in business, form connections, project plans, and seize hold of the enterprises of life, as if we were to live for ever on earth. In age another change comes over the spirit of our dream. We let go our hold of the ambitious projects of life. We retire from the busy whirl of excitement to the calm retreats of domestic quiet, and, with philosophic content and Christian resignation, await that last change which shall befall the children of earth.

216. *Design of transformations.*—Why these incessant changes of organized nature? Might not plant, and tree,

and insect, and bird, and beast, and man, receive at once a perfect and permanent form? We can only answer, that a dispensation of permanence pleased not the great Creator. Progressive development and succeeding decay enter largely into the code of laws, which the Governor of the universe has been pleased to give organic nature. So far as physical purposes are concerned, every species, and every individual of animate creation, has a work to do, a mission to perform, a destiny to fulfill. The annual plant thrusts out its leaves, puts forth its flowers, matures its seed, and dies. The insect lays aside its gross and earthly form, spreads its wings, flies to its appointed place, lays its eggs, and dies. Man comes forth in weakness, grows up in strength, plies, till he exhausts them, all his acquired energies to his allotted task, and dies.

All the changes, from birth to maturity, are but steps in progressive advancement to the great end for which physical life was given. When that end is reached, and the mission accomplished, the succeeding changes are but downward steps to the vast plain of dissolution, where all of mortal origin must at last repose.

217. *Death of animals.*—The law of mortality is universal. From its operation none of earth's children have ever escaped, except those favored ones of olden time, who were translated, and these passed away only in a form and manner different from the usual course of human life. In the very constitution of nature, as now presented to us, the elements of death exist, coeval with those of life. The seeds of life and of death are sown together. They lie side by side. The former spring up first, and come to maturity sooner, but the latter are sure to follow on. Life paves the way for death. The very means which nature uses to develop and sustain life, contribute to hasten on death. Were man never sick, and did no accident ever befall him, still he would die. The leaf of the deciduous

tree would fall at autumn were it never touched by frost, or shaken by wind. The very sap, which, by circulating through it during summer, has nourished and sustained it, has deposited in its pores particles of solid matter, which must impede the action of its living organs, and terminate its existence. The very blood, which circulates over man's body, and which furnishes him nourishment and means of growth, and without which he could not live an hour, leaves behind it a deposit which, from infancy to maturity, promotes the development, growth, and perfection of the physical organs, but which, after maturity, thickens, and stiffens, and hardens the muscles, cartilages, and bones of the living frame, until the organs, impeded and paralyzed, can no longer perform their functions, and man dies as surely and as naturally as the leaf falls. Death is natural—as natural as life. And yet, universal nature dreads it. The worm that crawls along your path recoils from it. The very grass beneath your feet shrinks at it. As for man, "all that he hath will he give for his life."

The dread of death is an instinct implanted in every conscious being. Its design is to protect us from the accidents which might frustrate, by an untimely death, the great designs and purposes of life.

We enter not, at this time, into a discussion of the origin of mortality. The subject involves moral and theological questions, which cannot well be treated in this lecture. How things might have been, had man not eaten

"Of the fruit
Of that forbidden tree, whose mortal taste
Brought death into the world, with all our woe,"

it becomes us not now to speculate. But how things are now we may inquire; and how those things which illustrate the wisdom and goodness of God, we may humbly and reverently investigate.

Taking things, then, as we find them, according to the

present moral constitution of humanity, we may, I think, safely assert, that the law of human mortality does operate favorably for the moral advancement of the human race. The law of progressive advancement seems universal. Every individual being in God's creation seems to advance by imperceptible stages, as in the growth of a plant or animal, from its embryo to its maturity. Arriving at maturity, and performing its mission, its destiny is accomplished; there is no longer, in the economy of nature, use for it, and, either suddenly or gradually, it passes away. Races and species, as well as individuals, may have their mission and their destiny. To it they advance by regular stages. The individual being may accomplish his work in a day or a century. The species, or the race, may require six thousand years, or even more. The individual accomplishes his work, both for time and for eternity, in a few years. He then passes from the stage of action, his work for time being done, and his work for eternity formed in such a mold, and stamped with such an impress, as precludes all change hereafter. But the species, the race of man, has not yet accomplished its work. Six thousand years of action are nearly past, and yet is not its mission performed. Its destiny is not yet fulfilled. The mission of humanity on earth requires, for the development of its object and the perfection of its performance, changes in the social organization not less frequent and radical, than those required in the animal organization for the development and maturity of the body. When a particle of the material organization has done its work, it is of no further use to the body. It is in the way. Becoming stiff and unyielding, it impedes the efficient action of the living organs, and should be removed, giving place to another particle, fresher, newer, and better adapted to the advancement of the body. So when, in the social organization, the individual has done his work, he becomes, from the very constitution of human nature, a hinderance to

the farther advancement of the race. His prejudices become unreasonable, his motions stiff, his will unyielding. He becomes to the social organization what an old, worn-out, effete particle would be to the living system. He is a foreign body. The development of the social system, the perfection of the organization, the advance to maturity of the race, requires his removal. Death removes him out of the way, and leaves thereby room for another better adapted to the changed and changing condition of things.

Thus, the law of change and renewal, which we described (§19) as one of the characteristics of organic beings, belongs to the race. We should as soon, and as reasonably, complain of the operation of the law in the one case as in the other.

Amidst all the changes of individual particles, the body remains the same body, animated by the same spirit, with the same passions and sentiments, though both body and mind are regularly advancing to perfection. So, amidst all the changes of individual members of society, the race remains one and the same, tending to the same goal, advancing to the same end, gradually developing its resources, and progressing in knowledge and virtue.

LECTURE X.

EVIDENCES OF DESIGN FROM THE STRUCTURE AND ADAPTATIONS
OF THE EXTERNAL SENSES.

The senses—Smelling—The theory of smell—Variety of odors—Use of smelling—Wise provisions—Taste—Its organ—Theory of taste—Use of taste—Relations of taste to other functions—Touch—Use of touch—Hearing—Importance of hearing—Cause of sound—Qualities of sound—Conduction of sound—Organ of hearing—External ear—The auditory passage—The drum—The eustachian tube—Chain of bones—Oval fenestra—The labyrinth—Theory of hearing—Curious facts illustrating it—Limit of hearing—Discordant sounds—Weariness from monotonies—Imaginary sounds—Relations and adaptations—Relations of sound to the voice—The music of nature—Seeing—The eye—Its shape—Coats of the eye—The cornea—The choroid coat—The iris—The pupil—The retina—Humors of the eye—Aqueous humor—Crystalline lens—Vitreous humor—Light—Laws of light—Refraction—Reflection—Refraction essential to vision—Phenomena of vision—Short-sightedness—Defect of vision in the aged—The eye an instrument—Adaptation to different distances—Aberration of sphericity—Chromatic aberration—Colors—Varieties of color—Pleasant colors—Sensibility of the eye—Specific power of the senses—Additional senses—Pleasures of sight.

218. *The senses.*—The external senses of the higher classes of animals are five—smelling, tasting, hearing, feeling, and seeing. By the senses animals are connected with the external world. Each sense has its appropriate organ and its appropriate work. The sense of smell gives us notions of odor; taste acquaints us with peculiar qualities of bodies in no other way discovered; hearing furnishes us the knowledge of sounds; feeling informs us of the essential qualities of bodies; and seeing gives us ideas of color.

219. *Smelling.*—The organ of smelling has received the general appellation of nose, or nostrils. It is placed, in all animals, near the mouth. The immediate instrument of smelling is a soft, vascular membrane, covering the internal surface of the nostrils, and traversed in every direction by branches of the nerve called the olfactory, or smelling nerve.

These branches of nerve are but slightly covered by the membrane, and are thus exposed to the action of every breath of air which passes through the nostril.

220. *The theory of smell.*—All bodies in nature are constantly throwing off from their surface indefinitely-small particles of matter. This matter is sometimes in a gaseous condition; but when bodies are very dry, it appears in atoms of solid substance, something resembling smoke, though not visible. It is generally called effluvia. These particles, whether gaseous, liquid, or solid, are constantly floating in the air. When we come into the neighborhood of an odoriferous body, this effluvia comes in contact with our nostrils. On touching the nostril they cause in us the sensation which we call smelling.

221. *Variety of odors.*—Every body known in nature has its peculiar odor, by which it may be distinguished from all other bodies. Some cause in us pleasant sensations—others extremely noxious and odious. In general, wholesome objects have a pleasant odor, while poisonous are exceedingly disagreeable. Not all animals, however, are affected in the same manner by odors. Some substances are offensive to man, yet sought after by brutes and insects.

222. *Use of smelling.*—The smell is of great use in selecting food. As before remarked, plants fit to be eaten by man have usually an agreeable odor, while those poisonous are nauseous. When the sense of smell is not vitiated by pernicious habits, it generally gives us correct information as to the quality of articles offered for food. Victuals having a putrid odor are rejected at once, being equally as offensive to our sense as hurtful to our constitution. Most animals are guided wholly by smell, in selecting their food. They easily distinguish by it salutary from noxious food, and choose the one, and reject the other.

But there is another advantage in the possession of the sense of smell. It is a source of pleasure, at least to man.

It is true, we sometimes are unpleasantly affected by disagreeable odors; but, in the great majority of cases, natural odors are pleasant. The flowers of spring, the mown hay of summer, the yellow harvest of autumn, and the sear and fallen leaf of winter diffuse an odor pleasant to all. Disagreeable smells never arise, except from the presence of some object which our safety requires us to avoid.

223. *Wise provisions.*—There will appear, on careful examination, several relations between the sense of smell and other functions of the body, exhibiting much wisdom. The cavity in which the organ of smell is placed is also used for the passage of the air in respiration. For this there was no necessity. Animals might breathe always by the mouth. True, it would prove sometimes inconvenient, as some other operations of life must, in that case, be suspended while breathing; yet it could be done. The structure, however, of man renders it more natural for him to breathe through the nose. Now, as odors are communicated to us only by the air, smelling becomes an incidental work, requiring no care nor attention on our part. We, therefore, become involuntarily aware of the presence of such bodies as should be avoided, in season to escape all danger. If, also, agreeable odors be present, we enjoy them without previous care and attention. Smelling and respiration, therefore, though utterly distinct functions, exhibit a striking relation to each other.

There is a relation between smelling and tasting. The same bodies which smell bad, usually taste bad, while agreeable odors are seldom followed by nauseous tastes. Thus, both smelling and tasting aid us in choosing food.

There are many instances of curious relation between the faculty of smell and the mode of life in particular species of animals. The dog can scent the game at a great distance, and can trace his master's footstep through the winding streets of a populous city. In animals possessing so

exquisite a sense, the olfactory membrane covers a very large surface, and is more amply supplied with nerves than in animals of duller sense.

Animals living in the water have not tubular nostrils like land animals, but, instead thereof, a simple cavity on each side of the nose, into which the water, impregnated with odors, flows, and communicates the sense of smell.

224. *Organ of taste.*—The appropriate organ of taste is the tongue, though the lips and all the internal surface of the mouth slightly aid the tongue. The tasting nerve is spread all over the upper surface, tip, and sides of the tongue, and gathered up into little knots, called papillæ. These papillæ are capable, when excited by the presence of food, of erection. In this condition they are very sensitive.

225. *Theory of taste.*—Bodies capable of causing the sensation of taste are called sapid bodies. When applied to the tongue they are moistened by the saliva formed in the mouth, and finely-dissolved particles touch the papillæ of the tongue, and thus the peculiar sensation called taste is excited.

226. *Use of taste.*—Taste is designed, as well as smell, to direct animals in choosing their food. When not depraved, it seldom misleads them. As a general rule, whatever is agreeable, naturally, to the taste is wholesome. Art and cookery may deprave the taste, so that it shall reject its meat, and revel in its poison. But generally, both in health and in sickness, it may safely be relied on.

Taste, also, is a source of superadded pleasure. Most animals enjoy their food. In order, however, to obtain the full amount of pleasure, which it is capable of bestowing, it should be left to its natural dictates, and time should be given for the food to be thoroughly masticated by the teeth and dissolved by the saliva.

227. *Relations of taste to other functions.*—The organ of taste, in all animals, is placed on the direct road to the

stomach. Not a particle of matter can enter that receptacle of the food, except by the way, at the commencement of which the taste stands sentinel. All substances seeking admission to the stomach must undergo its scrutiny. Its only power, however, is to decide on the character of the comer. It cannot arrest the intruder, but it may report him at headquarters. It is a faithful sentinel, and never reports incorrectly, though in case of disease it may fail to report at all.

The taste is related to the teeth, which masticate the food, while it applies its tester to the triturated particles. It is related to the saliva, which is always copiously formed while the taste is active. It is related to the stomach, which often rejects and ejects food, which the taste has previously condemned. It also gives us notice when the stomach is supplied, by ceasing in that case to afford us longer any pleasure.

228. *Touch*.—The organ of touch, or feeling, as it is sometimes called, is principally the skin. In some parts of the body the power is concentrated by an accumulation of nerve at some point. The tip of the tongue and the ends of the fingers in man are the points most susceptible of *this* sensation.

229. *Use of touch*.—The design of touch is to give us knowledge of two qualities of matter only—resistance and temperature. When we apply our fingers to any substance, or place any part of our body in contact with it, we feel a sensation, which we call touch, and which at once suggests to us the existence of some external body, which resists ourselves. Our ideas of shape, form, hardness, softness, roughness, and smoothness, are only modifications of resistance.

Temperature is wholly independent of resistance; and yet we derive our knowledge of it from touch. Heat and cold are reciprocal, or, rather, antagonistical qualities, not inherent in bodies, but yet inseparable from them. Approaching a

hot body, we experience a burning sensation. Touching a cold body, we are chilled. The design of God in forming us with this susceptibility to impressions of resistance, heat, and cold, was to protect us from destruction. Were it not for the sensation of touch, we should unknowingly dash our heads against a post, or rush into the fire, or perish with cold.

As in smelling and tasting, so in touch, the sensation is a source of pleasure. Contact with smooth bodies causes agreeable sensations. So mild temperatures diffuse a pleasant sensation all over the body. God has in this, as well as in numerous other instances, added pleasure to profit.

230. *Hearing*.—The organ of hearing consists of an external ear, varying in shape in different animals; a membrane stretched like a drum-head over a bony rim, and separating the external from the internal cavity; and a series or chain of small bones, connected with a nerve, called the auditory nerve.

231. *Importance of hearing*.—Without hearing there could be no oral language; but our only means of communicating ideas, one to the other, would be by signs, which, at best, are very imperfect. No literature could exist. Knowledge acquired by one generation could not be transmitted to the next. Man would rise little, if any, above the brute.

Hearing is also one of the sources of pleasure which God, in his love and wisdom, has opened for us in our earthly existence. Sweet sounds breathe all around us, in the air, on the earth, and in the water. The soul is charmed with music of bird, and of insect, and of reed, and of tuneful string, and, sweeter than all, of human voice.

232. *Cause of sound*.—Sound is caused by tremulous vibrations in material bodies possessing elasticity. Bodies capable of emitting sound are called sonorous bodies. When such a body is struck, the particles of matter in it vibrate, and tremble among themselves. This tremulous

vibration may be easily seen in a bell when struck. You may see it very clearly in a fork used by musicians in pitching tunes, or you may feel the vibration by placing the fork on the tips of your nose or tongue.

233. *Qualities of sound.*—Sounds vary in acuteness and in loudness. The more rapid the vibrations, the higher or more acute the sound. Slow vibrations give grave sounds, or sounds said to be on a low key. Loudness depends on the force with which the body is struck. A loud sound may, therefore, be either acute or grave, according to the capacity of the sonorous body for frequent vibrations. The acuteness of sound in stringed instruments depends on three circumstances—length, thickness, and tension. The shorter, smaller, and tighter a string, the more acute the sound. You may observe this on any stringed musical instrument. In wind instruments the acuteness varies with the calibre and length of the pipe. In the violin, when you desire an acute sound, you tighten the string. When you wish a loud sound, you draw the bow over the strings heavily.

234. *Conduction of sound.*—When a sonorous body at a distance from us is struck by any force causing vibrations, the motion into which the body is thrown is communicated, by the process called, in natural philosophy, action and reaction, to the air immediately in contact with the body. This stratum of air communicates its motion to the next stratum, and that to the next, and thus on until the air in contact with our ears communicates the vibration to the seat of hearing, and we have the sensation immediately following. The air in this process operates only as a conductor. Liquids and solids conduct sound equally as well as air, or even better. Place your ear at one end of a stick of timber, and let a watch tick at the other end, and you will hear it much more distinctly than if nothing but air intervened. The timber in this case does not conduct the sound, as is often supposed, by reason of the air contained in it, but by means

of its own power of conducting vibrations. The same bodies are often both sonorous and conductors of sound. Air is a conductor; and in wind instruments it is itself the vibrating body. The flute and fife are of no use, except to confine the air, and the holes in the instrument are only designed to vary the length of the column.

235. *Organ of hearing.*—The principal parts of the organ of hearing are the external ear, outer passage, drum, eustachian tube, chain of bones, oval fenestra, labyrinth, and auditory nerve.

236. *External ear.*—The use of the external ear is to collect the vibrating air. For this purpose it is peculiarly tortuous in shape. I know not that the characteristic of the curves of the internal surface of the external ear has ever been determined. It is evident that these peculiar curves are constructed on mathematical principles, so as to collect in the best possible manner the vibrations. Some animals are capable of moving the ear toward the sound. Man, on account of the ease with which he can move his head, needs not this provision.

237. *The auditory passage.*—The sonorous vibrations, being collected and concentrated by the external ear, are conveyed along the auditory passage to the drum. This passage extends in a winding direction, and has no opening inward, being closed by the drum. The width of the passage may be enlarged by opening the mouth. You may become satisfied of this by placing your finger in your ear, and then shutting and opening your mouth. This is probably the reason why people open their mouths when they listen. There is secreted within this passage an oily, resinous substance, called wax, whose use is to exclude the entrance of insects, and to preserve the canal in a condition proper for the conveyance of vibrations.

238. *Drum.*—The drum, or, more properly speaking, the drum-head of the ear, is a membrane stretched over a bony

rim, completely closing the passage from the external to the internal ear. It has muscles attached to it, by means of which it may be tightened or relaxed, very much like the head of the militia drum.

239. *Eustachian tube*.—From the cavity within the drum, there extends to the throat a tube, called, from the anatomist who first described it, the eustachian tube. It is in man about an inch and a half in length, widening from the ear to the throat like a trumpet.

The use of this tube is to furnish air inside the drum. All know that a common drum gives no sound unless air be freely admitted inside. Had the cavity beyond the drum been filled with confined air, the changes of bulk, to which this internal air would have been subject from the variable density of the external air, might have caused inconvenience and pain. Had an aperture been made for the admission of external air directly, as in the case of the common drum, inconvenience might have resulted from the variable temperature. Through the eustachian tube air from the lungs, already assimilated to the temperature of the body, finds ready access to the internal cavity.

240. *Chain of bones*.—We have already said that solid bodies conduct sound even better than air. Resort to their aid is had in conveying vibrations from the drum of the ear to the labyrinth. There is a chain of bones, consisting of four links, extending from the membrane of the drum to the membrane of the labyrinth. They are of curious shape, one resembling a mallet, another an anvil, and a third a stirrup. At their joints, unlike the articulations of other bones, there is no cartilage, as that might blunt the hearing. They are harder, and more brittle than bone usually is, thereby being better adapted to tremulous vibration.

Several little muscles are attached to these links, so as to relax or tighten the chain, as circumstances may require.

241. *Oval fenestra*.—At the internal termination of this

chain of bones is a membrane, closing what appears to be the entrance to the labyrinth. The last link of the chain rests immediately on the membrane, so that vibrations conducted along the chain are communicated to this membrane, called, from its resemblance to a window, the oval fenestra, and from that to the labyrinth.

242. *The labyrinth.*—This is the proper audience-chamber of the ear. It consists of several intricate winding galleries. It is lined throughout by a delicate membrane, in which terminate the extreme divisions of the auditory nerve. This nerve is thus spread, in minute ramifications, all over the labyrinth, and receives the vibrations conveyed to it from sonorous bodies.

243. *Theory of hearing.*—The sonorous body on being struck by any force vibrates. The air and other conducting bodies convey the vibrations to the ear. The external ear collects the vibrations, and the drum receives them. From the drum the chain of bones conveys the oscillations to the membrane covering the opening to the labyrinth. This membrane repeats them, and they are communicated to the delicate expansion of the auditory nerve, spread, as we have seen, all over the labyrinth. Here we lose the run of the sound. We can trace it no further. We say that the auditory nerve communicates it to the brain, and the brain to the mind, and thus the sensation of hearing is originated. But we know little or nothing about these ultimate points. There is some connection between the labyrinth and the brain, and the brain and the mind; but what is the nature or form of the connection no one can tell.

244. *Curious facts, illustrating the theory of hearing.*—Each and every sonorous body in nature has its own sound, or key-note. Whenever struck, it emits that note, and that only. Whenever its note is sounded by another body in the neighborhood, it will take up and repeat the sound. But it will not answer any other note. A bell, however struck,

hard or soft, emits the same note. If its note be sung or sounded near, it will repeat it. Thus bell-founders determine the musical letter to which each bell happens to be tuned, by sounding near it the various notes of the gamut, observing at what sound the bell answers. It will be silent until its own note is sounded, and then invariably tune up. The several strings of a piano are attuned to some definite note. Sound any note, either by other musical instruments or by voice, near a piano, and the string or wire attuned to that note will repeat it, while all the other wires remain silent. Each seat in a church, and every article of furniture in a room, will vibrate when its natural note is sounded.

The organs of hearing, in a similar manner, repeat the sounds communicated to them from sonorous bodies. But as these sounds are of every possible variety, from the lowest to the highest in the musical scale, the ear must adjust itself to every change. This is effected by the muscles of the drum, and of the chain of bones. When an acute sound strikes the drum, the muscles contract and tighten up the drum to the degree necessary to catch and repeat that sound, and the muscles of the bony chain do likewise. If a low or grave sound come along, the muscles relax so as to adjust the ear to it. It is as if one and the same wire of the piano should give every possible note in the gamut, by tightening and relaxing itself, according as a high or low note might be needed. This adjustment of the organs of hearing to varieties of sound, is an involuntary operation. We have no more control over it than over the circulation of the blood. We may, however, become conscious of the fact. When listening for a low sound, we are conscious of an involuntary effort to relax the auditory muscles; and, when trying to catch a high sound, we are pained at the effort to contract the muscles.

245. *Limit of hearing.*—We see in the last section the

reason of the limit of hearing. Sounds may be inaudible, either from being too low or too high. If a sound be so low or grave that we cannot so relax the muscles of the ear as to be in unison with it, we cannot hear it. And, on the other hand, if it be so acute that we cannot tune our ear up to it, we cannot hear it.

There may be sounds in nature both so low and so high, as to be utterly inaudible to human ears. Yet other beings may hear them, no matter how loud they are. If they be too high or too low for our organs, we must remain totally ignorant of their existence. The far-famed sage's music of the spheres may be a reality to beings of an order differing from us.

246. *Discordant sounds.*—The necessity of the change of tension, so as to receive various successive notes, explains the cause of discord. When the change becomes so rapid or so inconvenient that our organs cannot keep pace with the tone, discord is produced. It is for the same reason that we cannot pronounce certain letters in rapid succession. We cannot change the organs of speech with sufficient promptness.

247. *Weariness from monotonous.*—Monotonous sounds, long continued, become invariably painful. This is because the muscles of the ear get exhausted from long-continued and unchanged tension. In the same manner the muscles of the hand and of the leg become weary, from long-continued exercise of the same kind. Weariness from monotone becomes the more excessive, if the sound be either very high or very low.

248. *Imaginary sounds.*—We sometimes are conscious of sensations of sound, when no perception of a sonorous body exists. A traveler relates, that one Sabbath morning, as he was journeying along beneath a torrid sun, over the burning deserts of Africa, he seemed distinctly to hear the church-bells of his native village, far away in the British

island. We often seem to hear the voices of the absent, of the loved and the lost, calling us by name, and we start from our reverie, expecting to see the forms long since laid away from mortal sight.

It would seem that in such cases the organs of hearing vibrate from habit. Some strong mental emotion throws the auditory organs into the state to which they were accustomed, from the presence of the sound which now returns in imagination.

249. *Relations and adaptations.*—Both air and water, the only elements in which the higher orders of beings live, are well-adapted to conducting sound. Had air been created inelastic, no sounds, except those made in close contact with the ear, could have been heard. Sound made in a vacuum dies away without being heard. So would all sounds made in the air, if the air were not elastic. How wise, then, is the provision, that man should live and breathe in the very element whose properties adapt it better in general than any other to conduct sound. This exhibits one of the interesting relations of organized to inanimate matter. These relations are numerous in nature. We may have occasion hereafter to notice others.

250. *Relation of sound to the voice.*—The voice is a musical instrument, constructed with relation to sound. The organ of voice is located at the very point most convenient, as the air, in the process of respiration, must pass along the vocal tube. The vibrating body, in speaking, is the column of air contained in the windpipe, and put in motion by the muscles about the throat, and modulated by the tongue, lips, and teeth, and other auxiliary apparatus. The pharynx, which is the chief organ of voice, is shaped somewhat like a clarionet. To it are attached muscles, by means of which its calibre may be enlarged or diminished, so as to make high or low sounds.

251. *The music of nature.*—The most of the sounds of

nature are plaintive. The robin, the goldfinch, the blue-bird, the sparrow, all sing in rising semitones. The twittering of the wren, the chattering of the swallow, and the polytones of the mocking-bird, have an appearance of cheerfulness; but on listening long, you will feel the plaintive sadness stealing over you. The wind whistling through a forest of pines, makes music indescribably plaintive. The sound of the rivulet running over its pebbly bed, and of the waterfall tumbling over the precipice, is of the same character. Standing on the brink of Niagara, you will at first hear only a deep monotone. But listen, and you will hear, coming up from those dark caverns, sounds varied and strange, rising and falling in melancholy cadence.

252. *Seeing*.—Of all our senses seeing is certainly the most important, and it illustrates most beautifully the wisdom and goodness of the Deity. We therefore ask you to follow us patiently, while we trace out the numerous and interesting facts and relations involved in the subject.

253. *The eye*.—The organ of vision—the eye—is one of the most curious and highly-finished organs of the animal body. It is placed in man in the highest part of the face, so as to command a view of objects above, below, and around. It is movable, so as to be easily turned in any direction. It is double, but acts as one single organ. It is securely lodged in a bony cavity, to preserve it from the dangers to which, from its external position, it must necessarily be subject. It is protected by the eyebrows, which are two arches, designed, as the old philosopher, Socrates, first observed, to serve to the eye the same purpose as the eaves to a house, letting the moisture and sweat from the head drip down, instead of running into the eye. They also serve to protect the eye from excessive light, as by depressing them we intercept the rays of light. The eyelids are protecting curtains, to be drawn up and down at pleasure. They are in pairs, the upper one of each pair

being concave upward, and the lower concave downward, so that they cannot interlace. The eyelashes are winnowing-fans, to brush away the dust and insects, which entering the eye might cause inflammation.

But the structure of the eye itself is still more curious than that of its external appendages. We therefore proceed to give you as clear a description as we can, avoiding as much as possible technical terms, of the anatomical and physiological structure of the eye.

254. *Shape of the eye.*—The eye in form is spherical. It is not, however, a perfect sphere. The front part is considerably more prominent than the corresponding portion of a sphere. There is evidence of wisdom in the shape. A flattened body would never, as we shall hereafter see, answer the purposes of the eye. Great skill was necessary in adjusting the form accurately. If in any individual the eye become, either by congenital constitution or by accidental circumstances, too round, it produces near-sightedness. On the other hand, if it be too flat, the person can see objects only at a distance.

255. *Coats of the eye.*—The eye has three coats. The outer is called the sclerotic, or hard coat. It envelops about four-fifths of the globe of the eye, the remaining fifth being formed of the transparent cornea. The sclerotic coat is opaque, firm, and dense. Its use is to protect the eye, and to afford origin to muscles.

256. *The cornea.*—The cornea is placed on the front part of the eye. It is inserted into a circular groove in the anterior margin of the sclerotic coat, in the same way as a watch-crystal is inserted into the case. It is transparent, so as to admit the light. It is more round than the rest of the eye. It appears like the segment of a small sphere set on a large one. It is called cornea, from its slight resemblance to transparent horn. Its transparency is essential to vision. Had the opaque sclerotic enveloped the whole eyeball, utter

blindness would result. But when the sclerotic has covered all but about one-fifth of the ball, it suddenly ceases, and its place is supplied by a perfectly-transparent coat, curiously formed of several concentric plates. The cornea, disposed in any other part of the eye than the front, would be utterly useless. Surely, chance could never exhibit such design.

257. *The choroid coat.*—Immediately in contact with the internal surface of the sclerotic coat is another coat, called the choroid, formed principally of a tissue of blood-vessels and nerves, with a delicate cellular membrane interlaced through them.

When this coat has lined the whole of the sclerotic, and approaches the cellular groove in which the sclerotic gives place to the cornea, the choroid also ceases, and its place is supplied by the iris, which we shall more fully describe in another section.

The vessels of the choroid coat secrete a dark-colored matter, called black pigment. The use of this paint is to absorb all scattering rays of light. We shall see, in another section, that such rays interfere with distinct vision.

258. *The iris.*—The iris is a continuation of the choroid coat, as the cornea is of the sclerotic. It conforms in size to the cornea. It is not round, but flat, leaving a space between it and the cornea like that between the crystal and dial-plate of a watch. The color of the eye, as blue eye, black eye, and hazel eye, depends on the color of the iris, which varies in different individuals.

259. *The pupil.*—There is in the iris an opening called the pupil. If we look into the eye of another, or into our own reflected in a mirror, we shall perceive a little image of our face, like a very minute child, or little *pupil*. From this circumstance the name is given to this aperture in the iris, which serves to admit the rays of light. The pupil is surrounded by a sphincter muscle, which contracts in the light, and dilates in the dark, thereby adapting the eye to

different degrees of light and shade. All the light necessary for vision must enter through the pupil. If we are in a strong light, so that it might injure the delicate texture of the eye, the pupil contracts, and thereby excludes the excess of light. If we enter a room deficient in light, the pupil dilates, so as to admit more rays, thereby enabling us to see in the dark. If you will examine your own eye by a mirror, you may easily see the process. Hold the mirror between you and the window, and you see the pupil contracted. Again, hold it before you, looking toward a dark corner of the room, and you will see the pupil dilated. By rapidly moving the glass you may even see the gradual change which the pupil undergoes. While sitting at evening in a well-lighted room, the pupil is much contracted. On going suddenly out you cannot see, because the contracted state of the pupil does not admit sufficient light. But, on remaining out a short time, you can see better, because the pupil gradually dilates. On a bright day of winter, when the ground is covered with snow, you cannot see when you first enter a room, because the strong light reflected from the snow has contracted the pupil. The muscles which surround the pupil, are of the involuntary kind. They act spontaneously, without any care from us. It is well that they do, for otherwise the eye might often be injured by sudden changes of light and shade. There are two muscles employed in the business. One is formed of concentric rings, like a nest of hoops. By contracting, this closes the pupil. The other is formed of rays, arranged similar to the spokes of a wheel. By contracting, this dilates the pupil. The presence of light causes the annular muscle to contract, while its absence causes the radiant one to act. Why this difference? Why should the same cause produce opposite effects on muscles of the same material constitution, and placed in actual contact with each other? Surely divine wisdom is exhibited in this arrangement.

In the lower animals the pupil varies greatly in size and in shape. Some species of beasts and of birds have great power of expansion of the pupil, and therefore they see well, even by night. Unless, however, they have a corresponding power of contraction, they are blinded by excess of light in the daytime. The owl can see well by night, but is greatly perplexed by day.

The pupil in man is a perfect circle, but in animals it assumes various forms. In the cat, and in several other animals, and in birds of prey, it is elliptical, the longer axis being vertical, to enable them to see well above and below. In herbivorous animals the longer axis is horizontal, enabling them to see more extensively on the direction in which their food must be sought. This arrangement is not more obvious than wise.

260. *The retina.*—The inner coat of the eye, being formed of ramifications of the optic nerve, constituting a species of net-work, is called the retina. This extends over all of the eye, except the front. The part of the eye occupied by the iris and the cornea seem to have been left free from the extension of the retina, as well as of the sclerotic and chorioid. The retina is the seat of vision. On it is formed a picture of every object on which we look, and by means of that picture, in some mysterious way, we obtain the sensation of sight.

261. *Humors of the eye.*—Having explained the coats, we must now call attention to what is usually called the humors of the eye. The coats resemble the shell of a cocoa-nut, inclosing fluids within—or the skin of an orange, containing parts important in the economy of nature.

262. *Aqueous humor.*—We have seen that there is a space left between the cornea and the iris. This space is filled by a liquid much resembling pure water. Through the pupil it communicates with a smaller space behind the iris. The aqueous humor fills, therefore, both the anterior

and posterior chamber of the eye. Its use, as we shall see, is to refract the rays of light.

263. *Crystalline*.—The crystalline humor lies behind the aqueous. It is of much firmer consistence resembling very thick jelly, or soft gristle. Its form is that of a double convex lens, and hence it is usually called the crystalline lens. It is formed of concentric plates, or layers, which increase in density and hardness from the circumference to the centre. This variation in density is of great importance, as we shall see.

264. *Vitreous humor*.—Two-thirds of the cavity of the eye is occupied by a transparent, gelatinous fluid, very much resembling the white of an egg, and called, from some fancied resemblance to melted glass, the vitreous humor. The use of it, in connection with vision, we shall see.

265. *Light*.—Before explaining the process of seeing, we must briefly describe the nature and properties of light.

Every one knows what light is; and its phenomena, or laws, are well understood; but its nature is obscure. Newton, and most of the earlier opticians, held that light consists of actual particles of matter emitted from the luminous body. Descartes, Huygens, Euler, and many of the later philosophers, believed that light is transmitted by means of the vibrations, or undulations, of a peculiar fluid, of extreme tenuity and elasticity, diffused throughout the universe. According to this theory, the fluid is only the medium of light, as the air is the medium of sound, the vibrations following each other, as wave follows wave. But, according to the former theory, there is a chain of particles, moving with great velocity from the luminous body to the eye. All the phenomena of light may be explained equally well on both theories. It appears, however, that the general language and mode of expression of most writers on the subject of optics conform to the theory of Newton. Bodies capable of emitting light are called luminous bodies. They

are of two classes—those which shine by their own light, as the sun, or a star, or lamp, and those which shine by borrowed light, as the moon, planets, and visible objects in nature.

266. *Laws of light.*—The principal laws of light, so far as vision is concerned, are two—refraction and reflection.

267. *Refraction.*—Some bodies in nature permit light freely to pass through them. These are called transparent bodies. The atmosphere, water, and glass, and several other substances, are transparent. If these bodies are everywhere of uniform density, light passes easily through them, in perfectly-straight lines; but if they vary in density, the ray of light, as it passes from one layer to another of different density, is bent out of its course. Thus, light passing from air into water or glass, is bent. This bending is called refraction. Rays starting from a luminous body, in lines parallel to each other, continue on in perfectly-straight lines, maintaining everywhere their parallel direction, so long as the medium in which they move continues of uniform density; but if they pass from one medium to another more dense, they are bent from their parallel course, and are converged so as to meet in a point which is called a focus. If, on the other hand, they pass into a medium less dense, they are bent from their course, so as to separate, and go off at a divergence from each other.

268. *Reflection.*—When a ray of light, in its passage, meets an opaque body, inasmuch as it cannot pass through it—for only transparent bodies suffer light to pass through them—it must either enter the body and remain there, in a state of absorption, or be sent back whence it came. In general, a portion of the light is absorbed, and the remainder sent back. This rebounding back, like a ball thrown against the wall, or on the ground, is called reflection. The ray is returned in the exact direction in which it came, only when it falls perpendicular on the reflecting surface. If it

fall obliquely, it is reflected obliquely on the other side, so that the angle of incidence and of reflection are equal. If you throw a ball perpendicular on the ground, it will rebound perpendicular, so that you can catch it; but if you throw it obliquely, it will rebound from you, so that one must stand some distance off to catch it. If you stand directly before a looking-glass, the light from your face falling perpendicular on the glass, is reflected in the same direction, so that you are visible to yourself; but if you stand a little on one side, the light from you falls obliquely on the mirror, and one must stand as far on the other side in order to see you. Such is reflection.

269. *Refraction essential to vision.*—If the retina of the eye received the light from surrounding objects just as it comes from them, we should have no distinct vision, but only a vague notion of light. An image of the object must be formed by refraction on the retina, in order that we may see. There is a little machine, called the camera obscura, which illustrates the process of seeing; or the operation may be illustrated by the room in which you are now sitting. Close all the doors and windows of the room, except one little aperture. If all the light, except what enters by the small orifice, be excluded from the room, there will be seen, on the wall opposite the opening, an image of all objects from which light is received through the aperture. If a convex glass be placed in the aperture, a much more perfect and distinct image will be formed. In this case, however, it is necessary that the wall should be at the focus of the lens. If it be not, a screen must be held at the focus to receive the picture. Daguerreotypes are taken on this principle. A perfect image of the object is formed, and fixed on a plate, suitably prepared to receive it.

270. *Phenomena of vision.*—We are now prepared to explain the process of vision. From surrounding objects light falls on the front part of the eye. It passes through

the transparent cornea. By the aqueous humor it is refracted, so that more rays enter the pupil than fall on a corresponding surface of the cornea. By the pupil the rays enter the inner chamber of the eye. In their passage they meet the crystalline lens. By this they are refracted still more than by the aqueous humor. They then pass on through the vitreous humor, and fall on the retina, where a perfect and distinct image of the object is formed. In a well-formed eye the refractive power of the humors is just sufficient to bring the rays to a focus, and thus form a distinct image, precisely on the retina; but in a defective eye the rays may be converged to a focus before they reach the retina, or after they have passed it. In either case there is no distinct vision.

271. *Short-sightedness*.—When the structure of the eye is such, that the rays converge to a focus too soon, the person is said to be short, or near-sighted. This defect arises from too great refracting power in the eye. Refracting power may vary either from different density or different shape of the humors. The more dense the humor and the more convex the shape, the sooner will the rays converge. Unusual convexity of the cornea would cause the aqueous humor to assume greater convexity, and thereby increase its refractive power. The crystalline lens, also, is naturally much more convex in some persons than in others. In eyes thus constituted, the rays of light, from objects held at the usual distance, entering nearly parallel, are brought to a focus just behind the crystalline lens, long before they reach the retina, and indistinctness of vision is the inevitable result. By holding the object near the eye, the rays enter divergent, and the focus is thrown farther back, so as to form the picture in the right place.

The remedy for this defect is found in concave glasses. The concavity of the glass contracts the convexity of the humors. One affected with near-sightedness may usually

find, at an optician's shop, glasses exactly adapted to his eye, so that with them he can see as well as other persons. There is a mechanical method of remedying this defect. It consists in gently pressing the ball of the eye outward, by passing the finger from the corner of the eye next the nose to the outer corner. By frequently manipulating the eye in this manner, the convexity may be diminished.

It is very unpleasant to be near-sighted. Persons thus affected should seek a remedy. Science has discovered a remedy in concave glasses. They should be used, unless the manipulating process should prove equally successful.

272. *Defect of vision in the aged.*—In age the sight fails on account of too feeble refracting power of the eye, caused either by too little density or too little convexity of the humors. The defect is exactly the reverse of near-sightedness, and must be remedied by precisely opposite means—by convex glasses, or by manipulating the eye from the outer corner inward toward the nose. This is usually the defect of age, because the convexity of the eye diminishes with years.

273. *The eye an instrument.*—The eye is the instrument of the mind in seeing. It does not itself see. It only enables the mind to see. It is to the mind what the telescope or the microscope is to the eye. In the microscope the image of the object is formed on a screen. That image is transferred to the eye, and the mind sees. In the telescope the image of the object is formed in the instrument, and reflected by a mirror to the eye, and the mind sees. Without the intervention of these instruments the image of a visible object is formed directly on the eye, and the mind sees. The optical instruments—microscope and telescope—have been carried to great perfection; but the eye excels the utmost efforts of art. There are several particulars in which the eye exhibits wisdom in design and skill in execution, which the most finished artist is unable to equal. Some of the particulars we proceed to notice.

274. *Adaptation to different distances.*—When we have adjusted the telescope to an object near at hand, and then turn it toward a remote object, we cannot see the latter distinctly, until the instrument is again adjusted. Having moved the parts so as to see clearly the distant object, if we then turn the instrument toward the nearer one, the latter becomes indistinct, and a readjustment is necessary. This is a necessary consequence of the optical law, that the distance of an image from the lens which forms it varies with the distance of the object from the lens. Were the eye constructed in this respect like the telescope, it would be impossible to obtain that variety of extent in view we now possess. My eye being now adjusted to the distance of the paper on my desk before me, I could not see the clock that ticks on my mantelpiece, nor the beautiful landscape from my window; yet I can easily see the smallest letter on the page before me, and the waving trees far in the valley below me, without any effort or intention on my part, but by an involuntary operation.

It is not certainly known by what means the eye thus adapts itself to so different distances. No artist has been able to manufacture any optical instrument with this power of adaptation. The refracting parts of the eye must undergo some change, either in form or position. When we suddenly change from a near to a distant object, we are conscious of some alteration in the eye, but what it is we cannot tell. If, as is most probable, there is a change in the form of the refracting substances, it is curious that such change should happen involuntary and spontaneous, whenever the position of the eye requires it.

275. *Aberration of sphericity.*—Opticians have found, in the construction of telescopes, a difficulty arising from what is called aberration of sphericity. For forming distinct images it is necessary that all the rays passing through a lens should be brought to the same focal point. But rays

passing through a lens of spherical form do not all converge to the same point. Those passing through the outer edges of the lens converge more rapidly than those which pass through the centre. The focus, therefore, of the central rays is more distant than that of those passing through the edges. The diameter of the space over which the rays are thus spread is called the aberration of sphericity.

This error occasions a serious difficulty in the way of all telescope-makers. By excluding all the rays except those which pass through the centre, the difficulty would be removed; but then so much light would be by that means shut out, that the object would appear very indistinct. It is found, however, that if the lenses, instead of being spherical, be elliptical, or sections of hyperboles, the difficulty may be overcome. The reason of this is, that, inasmuch as the central point of the lens refracts too little, and the marginal parts too much, if we can increase the convexity of the centre and diminish that of the margin, we shall secure the desired result. But the ellipse and hyperbole are curves, whose convexity diminishes from the centre to the margin of any section. Now, it actually happens that both the aqueous humor and the crystalline lens are, in shape, very nearly ellipsoids. Thus it appears, that the highest triumph of mathematical and optical art is only an imitation of nature.

But there is another means of overcoming spherical aberration in the eye—a means which art cannot imitate. Opticians have succeeded in making lenses of elliptical shape, but they have not been able to make a lens whose central and marginal parts should differ in density. The lens must be of uniform density throughout. It is not possible for man ever to make a lens otherwise. Yet the crystalline lens of the eye is made of concentric layers, increasing in density as you approach the centre. The consequence of this structure is, that the rare layers on the

margin refract less, and the inner ones near the centre more, than from their shape alone they otherwise would.

By, therefore, the elliptical shape of the refracting parts of the eye, and by the varying density of the parts of the same lens, spherical aberration is entirely overcome. It is rather difficult to make this subject intelligible to minds not drilled in mathematics; but when understood, it will exhibit proof of unsurpassed and unsurpassable wisdom in contrivance and skill in execution.

276. *Chromatic aberrations.*—An object seen through a glass prism appears tinged with the various colors of the rainbow. This arises from the unequal refraction of the colored rays of light. A single beam of light, as it proceeds from any luminous body, though appearing white or colorless, is yet composed of seven colored rays, which may be dispersed by a lens, so as to assume each a distinct direction. When, therefore, a quantity of light passes through a refracting medium, the colored rays, which in their mixture appear white, are separated from their combined state, and the red rays take one direction, the blue another, the green another, and the violet another still. Objects thus seen through a microscope, or telescope, unless the defect be remedied in some way, appear not of their natural color.

But, in addition to the change of color, there is indistinctness of form in the image of all objects seen through lenses. This indistinctness arises from the fact, that the colored rays differ in refrangibility. All the violet rays in the beam of light, after being separated from their associates, are brought to a focus at a certain point. The red rays, likewise, separated from the rest, are also brought to a focus, but not at the same point with the violet. The violet are much more easily refracted than the red, and the focus of the former is much nearer the lens than that of the latter. The green, blue, orange, yellow, and indigo-colored rays are each brought to their own focus. The consequence of this is,

that if the object be held at such a distance as to bring its image in the focus of the red rays, the violet will form a blur on the image, rendering it indistinct. On the other hand, if the image be formed at the focus of the violet rays, it will be rendered indistinct by red fringes surrounding it. Thus, there is both false coloring and indistinctness in the picture of objects seen through a lens, or any other refracting substance. This defect in coloring and distinctness is called chromatic aberration.

Philosophers and opticians were for a long time much puzzled with this difficulty. It was desirable to obtain an image of the true color of the object, and it was essential to avoid indistinctness. But the thing could not be accomplished by the ordinary glasses. At last one optician, more wise than the rest, thought of inquiring how the thing was accomplished by nature. We see things of their true color, and see them distinctly, and yet the image of them on the retina is formed by refracting substances, like the glasses of the telescope. He observed that there are three refracting substances in the eye—the aqueous humor, crystalline lens, and the vitreous humor—each differing from the others in density and refracting power. He therefore imitated this contrivance by introducing into the telescope several glasses differing in refracting power. He succeeded in obtaining an image much more satisfactory, but yet not quite free from color, being tinged on one side with a claret-colored, and on the other with a greenish fringe. He looked again at the eye, and observed that two of its refracting substances are fluid, and the other solid. He therefore tried his hand again at imitation, and introduced into the telescope a combination of solid and fluid lenses, differing in refracting power, and now he succeeded perfectly. Telescopes provided with this arrangement of glasses are perfectly free from chromatic aberration.

277. *Colors.*—In explaining chromatic aberration we have

had to anticipate some remarks on colors. Color is not an essential property of material bodies. It is accidental, depending on the absorbing and reflecting power of the object. If an object permits all the light falling on it to pass freely through it, the object will be invisible. If it reflect all the light, it will appear white. If it absorb all the light, it will appear black. If it absorb all but the green, and reflect that, it will appear green. If it absorb all but the blue, and reflect that, it will appear blue. Whatever color the object reflects to the eye will appear to us the color of the object. Change of color in an object arises from a change in its reflecting power.

278. *Varieties of color.*—Although there are but seven primary colors in light, and some philosophers think these may be reduced to less, yet the variety formed in nature by the combination of these few is very great. You know that a painter, by mixing paints, may obtain any shade of color he pleases. In nature no two species of matter is of exactly the same color. The prevailing tint of vegetation is green, but how great the variety in shade! Look over a landscape. Observe the corn, wheat, oats, and every species of grass. See what endless varieties of green. Look at the trees. The oak, ash, maple, beech, elm, pine, fir, apple, pear, peach, plum, cherry, all may be distinguished, each from the others, by color. These varieties depend on the peculiar arrangement of the particles of matter composing each object. All vegetation is made up of the same elementary constituents, in nearly the same proportions. But in the arrangement of the particles of matter one species differs from another, and this arrangement gives the variety in color. How wise must be the mind to design, and how skillful the hand to execute such infinite varieties of arrangement, as to afford such differences in color! Nor is the wisdom less evident from the indirect mode in which its purposes are

effected. The vital organs of each species of plant and tree are made to produce the effect by a natural law. The organs of the beech so arrange the particles of which the leaf is composed, as to cause them to reflect that particular modification of green which is peculiar to that tree. The organs of the rose so arrange the particles composing the flower, as to reflect the varieties of red usually seen in the species. In variegated flowers how exquisite must be the contrivance by which such varieties of color appear in the same minute space! Surely there is more wisdom in designing the organs which produce these various shades of color, than would be evident in directly laying on the colors with a painter's brush.

279. *Pleasant colors.*—It is known to every one that some colors are more agreeable than others. Some are agreeable when seen seldom, but become disagreeable on continuance. The colors in nature most frequently recurring, and most extensively diffused, are blue and green—the blue of the sky, and the green of vegetation. We must see these colors whenever we look on the earth or the heaven. And what colors are so beautiful? What induce so agreeable a state of mind? What are more naturally adapted to the eye, never causing it pain? The relation between the diffusiveness of these colors, the structure of the eye, and the constitution of the mind, is remarkable. Cover the earth with a carpet of any other than green, or spread over the sky a curtain of any other than blue, and our eyes would be pained, and our souls sick.

We see in this, as in a thousand other examples in nature, evidence, not only of the wisdom and goodness, but of the unity of the Deity. Wherever relations between two things of independent nature are found, there is evidence that one mind alone has designed, and one hand alone executed the work.

280. *Sensibility of the eye.*—The outer parts of the eye are so keenly sensible as to have passed into a proverb. The Christian poet, in his aspirations for a lively conscience, says,

“Quick as the apple of an eye,
O God, my conscience make.”

This sensibility is wisely designed for protection against external injury. Instinctively we start from any and every thing which threatens the eye.

But while the external parts are so exquisitely sensitive, the internal are totally insensible. Nothing but light makes any impression on the retina. The optic nerve may be cut and mangled without the slightest touch of pain to the patient. This is another proof that pain is a specific endowment to such parts, and such only of our living frame, as are, from their position, exposed to injury.

281. *Specific power of the senses.*—The eye is affected only by light, the ear by sounds, the nose by odors, the mouth by tastes, and the touch by contact with external bodies. Yet the anatomist nor the chemist can discover the slightest difference between the material, the composition, and the structure of the nerves of seeing, hearing, smelling, tasting, and feeling. Each sense is specific in its purpose; but how came it so? Why should not the optic nerve be susceptible of impressions of sound, or the auditory of seeing? God has, in his wisdom, designed each sense for its own work, and made it capable of performing that in perfection, but no other.

282. *Additional senses.*—Man has five senses. Other animals have less. All of course have feeling, though in very different degrees. Probably most living beings have taste and smell. But many are destitute of hearing; or, at least, no organ of hearing can be discovered. If any species be destitute of any one sense, it must for ever remain ignorant of the knowledge of which that sense is the avenue. A being without hearing could know nothing of

sounds, and without sight could know nothing of colors. It would be unwise for a species of animal having only three senses to conclude that no species could possibly exist having more than three. It may be equally unwise for us to conclude that there can exist nowhere in the universe beings having senses of which we know nothing. By the five senses which we possess we are connected with the material world, of whose existence we should, without these senses, be profoundly ignorant. Spiritual beings may be connected with the spiritual world by senses much more exquisite than those which connect us with earth. The souls of the loved ones who have gone from among us may not be agitated by the jarring and discordant sounds of human life, but with organs of whose structure we know nothing: they may listen to the music of the spheres, and be charmed with heavenly harmonies. On their eyes may not be formed the images of deformity, and scenes of aversion, from which we on earth would often gladly turn away; but yet they may see sights, which no mortal ever saw—objects of exquisite beauty, too beautiful to be painted on the material structure of human sight. Sounds there are we never heard, sights there are we never saw; for our organs are too dull to receive them. Sensations there may be we never knew, because we have no organs adapted to receive them. There may, therefore, be, in our heavenly and immortal state, avenues of knowledge of which we can have no consciousness in this mortal state. The embryo being, in its maternal prison-house, knows nothing of the sounds and the light of this beautiful earth. Our present may be but the embryo of our future selves; and we may, when once we emerge from the darkness of mortality to the light of immortality, find ourselves at once in possession of senses as new as were seeing and hearing when we came into this world.

283. *Pleasures of sight.*—It might be difficult for us to

determine of which sense the inferior orders of animals might be deprived with least injury to the functions of life; but we should be at no loss in determining which of the senses man might most illy spare. It is conceded that the loss of hearing interferes most seriously with the acquisition of knowledge, inasmuch as so large a portion of our knowledge is derived from conversing with our fellow-men. But so far as knowledge is derived from observation, incomparably more is received by sight than by hearing.

But, as a source of pleasure, sight is vastly more important than all our other senses. Without it we should have no idea of beauty, whose forms God, in his mercy and love to us, has been pleased to imprint on the sky, and the earth, and the waters. The blind child never saw his mother's smile, nor looked on the gladness of nature. He never saw sun, nor moon, nor stars. The lovely landscapes of earth are all naught to him. All the beautiful prospects of nature are but a dreary blank.

“Thus with the year
Seasons return; but not to him returns
Day, or the sweet approach of even or morn,
Or sight of vernal bloom, or summer's rose,
Or flocks, or herds, or human face divine;
But cloud instead, and ever-during dark
Surrounds him—from the cheerful ways of men
Cut off, and, for the book of knowledge fair,
Presented with a universal blank
Of nature's works, to him expunged and razed,
And wisdom at one entrance quite shut out.”

LECTURE XI.

ADAPTATION OF THE ELEMENTS TO THE WANTS OF MAN.

The elements—The atmosphere—Constitution thereof—Transparency of the atmosphere—Elasticity—Reflective power of air—Refractive power—Motion of the atmosphere—Advantages thereof—In equalizing the temperature of the earth—In producing rain—In removing moisture—In commerce—Respirable properties of air—Water—Fluidity—Neutral properties—Evaporation—Importance thereof—Abundance of water—The solvent power of water—Provision for preserving the fluidity of water—Water an indispensable substance—Heat—Expansive power—Conduction—Metals conductors—Water a non-conductor—Air a non-conductor—Fur, wool, and feathers non-conductors—Snow a non-conductor—Radiation of heat—Radiation modified by color and surface—Sources of heat.

284. *The elements.*—We have explained (§15) what we mean by elements, or elementary substances, and have remarked that the ancients, from the great importance of air, water, heat, and earth, considered these substances as the four elements out of which all other things were made. This classification is, unquestionably, incorrect; and yet it was convenient for their purposes, and it may be convenient for us in this lecture to use the word element in much the same way, and under the general term, elements, discuss the nature, relations, and adaptations of air, water, and heat to the wants of man.

285. *The atmosphere.*—From the lowest depths of earth to the distance of at least fifty miles above its surface, there extends in every direction, filling up every crevice, and even mingled with the waters of the sea, a transparent fluid, called the atmosphere. Its presence is essential to every form of life. Without it not one man, not one beast, not one bird, not one fish, not one insect, not one tree, not one herb, could exist on the broad face of earth, or in the waters of ocean. Let it depart, and darkness and death would throw an impenetrable shroud over earth.

The constitution and properties of the atmosphere afford us some fine illustrations of wisdom and goodness.

286. *Constitution of the atmosphere.*—The atmosphere is composed of two gases—oxygen and nitrogen. The gases are mixed, and may be easily separated. The proportion of the parts in mixture is four-fifths nitrogen to one-fifth oxygen. These proportions are invariable; air being taken from every part of the earth, and under all varieties of circumstance, of temperature and moisture, containing precisely the same proportions. And yet oxygen is constantly disappearing, as every animal is using it in breathing, and every flame of fire or lamp is consuming it in combustion. How, then, is the supply kept up? God, in his wisdom, has made the vegetable kingdom the means of furnishing the supply. Every leaf on every tree, and every spire of grass on the surface of the earth, is at work manufacturing oxygen. Every hour of the day, incited by the light of the sun, oxygen is emitted from these little laboratories of nature; and so perfect is the adjustment of agencies, that the supply never fails, and never exceeds the demand. When it is winter with us, vegetation in the tropics and in the southern latitudes is still busy; and so continual is the motion of the air, that every part, from Cape Horn to Greenland, and from India to Oregon, is properly mixed, and ready for use. It is wise that the proportions should remain invariable. Could the proportion of oxygen be diminished, the air would become too much diluted, and unfit for the purposes of respiration. Could it be increased, it might corrode the physical system of animals, and produce febrile action. Could the increase be continued without limit, it would reach that proportion in which oxygen and nitrogen combined form nitric acid, or aquafortis; for, be it observed, while the proportion of four-fifths nitrogen and one-fifth oxygen mixed form atmospheric air, the inverse proportion, or nearly so—that is, about

three-fifths oxygen and two-fifths nitrogen—combined form nitric acid. Now, if the care of Providence were not exerted by uniform law or by direct interposition, the proportions of oxygen and nitrogen in the air might become those forming nitric acid. Then should, by some sudden flash of lightning, the temperature be raised to the point of combination, the atmosphere would disappear with a great noise, and the earth be overwhelmed by a shower of nitric acid.

And why does this uniformity prevail? Was there, in the nature of things, any necessity for this exact and invariable proportion? None at all, of which we can conceive. Chance might have left it at random. But a wise and benevolent God has fixed the limit by invariable law. He has so adjusted the amount of influences of the several agencies of respiration and combustion, on the one hand, and vegetation, on the other, as to keep up, through a succession of ages, the exact proportion necessary for the purposes he designed.

287. *Transparency of the atmosphere.*—The atmosphere is nearly perfectly transparent—more nearly so than water, or any other fluid. In small quantities it is absolutely transparent, permitting us to see bodies through it, as if nothing intervened. But when we look at it in large masses, as up toward the sky, or horizontally toward a mountain landscape, it reflects a beautiful blue. The transparency is designed to afford free passage to light, that we may see objects clearly. Most admirably does it accomplish this purpose. How totally would the whole appearance of things be changed, if the atmosphere were opaque, like smoke or fog! And yet no man, wise as he is, can tell by what difference in arrangement of particles some bodies are transparent and others not.

288. *Elasticity.*—The air is exceedingly elastic—indeed, one of the most elastic bodies in nature. To this property it owes its power of conveying sounds. An inelastic body

would be totally useless as a conductor of sound. Were the air inelastic, the evening bell, which is now sending forth its mellow tones over the landscape, might still ring on, but no one would hear it, unless his ear were in contact with it. The beautiful bird, that is now sending forth from the topmost branch of the willow such varied notes as seem hardly of earth, might still sing on, but neither you nor I could hear him. The voices of loved ones would be silent to us, unless they were uttered in contact with our ear. All nature would be dumb, or, rather, we should be deaf.

289. *Reflective power of air.*—The air, we have said, is transparent, easily permitting light to pass through. It is remarkable, too, that it has the power of reflecting light. We should naturally conclude that, inasmuch as transparent bodies suffer light to pass through them, and opaque bodies absorb or reflect it, the same body could not be both transparent and reflective. But the fact is, no body in nature is perfectly transparent, permitting all the light falling on it to pass through it. The air differs from opaque bodies in the fact that it absorbs no light, but either suffers it to pass or reflects all falling on it, retaining none. The greater part of the rays from the sun pass through the air, and reach the earth. From the earth, and the bodies on its surface, the light is reflected again to the atmosphere. The reflected rays being weakened in their transit, have less power to pierce the atmosphere than when they first came from the sun, and some of them, particularly the blue, are reflected by the atmosphere, giving that beautiful blue tinge, for which the sky, which is nothing more than the distant atmosphere, is remarkable.

Now, had the atmosphere no power of reflecting light, the whole firmament, except the points in which appear the sun and stars, would be deep black. No light appearing except in these luminous spots, if we looked directly at

the sun, its light would meet our eyes; but if we looked away from it to any other part of the heavens, all would appear deep dark. Bright sunshine would never be known in an unreflecting atmosphere. Gloomy, indeed, would be the face of Nature, if no light were reflected from the sky or the clouds.

"Were it not," says Sir John Herschell, in his treatise on astronomy, "for the reflecting and scattering power of the atmosphere, no objects would be visible to us out of direct sunshine. Every shadow of a passing cloud would be pitchy darkness. Every apartment into which the sun had not direct admission would be, at noonday, involved in midnight obscurity. After the sun and moon are set, the atmosphere still sends us a portion of their light, not, indeed, by direct transmission, but by reflection of the vapors, and minute solid particles which float in it, and, perhaps, the actual material atoms of the air itself."

290. *Refractive power.*—The refractive combined with the reflective power of the atmosphere, affords us the beauties and conveniences of morning and evening twilight. When the sun sets, we are not plunged suddenly into total darkness. The rays of light are bent by the refractive power of the air, so as to remain visible for a long time, and are reflected, often, in many varied and beautiful colors, from the atmosphere and clouds. In the morning, too, the sun does not suddenly appear, dazzling unaccustomed eyes with a painful glare of light; but, by the refractive power of the atmosphere, his approach is heralded by the dawn—at first a faint streak of light, gradually extending, until the full morning light cheers the world.

291. *Motion of the atmosphere.*—The air is peculiarly susceptible of motion. The slightest disturbance of its equilibrium at once raises a breeze. The principal disturber of its quiet is heat. The least change of temperature, either local or general, produces motion of the air. Heat

has the power of expanding, and, of course, rendering lighter, in proportion to the bulk, all bodies. When air expands by heat, the colder air in the neighborhood, by its elasticity, presses on and displaces the lighter or rarefied air. The equilibrium being thus disturbed, the air from a distance partakes of the motion, and the whole atmosphere, for a great distance, becomes agitated. Great heat is not necessary to raise the wind. Relative differences of temperature alone are required. The air may be all very cold, but if that in one place be colder than that in any neighboring place, motion will be produced. In most parts of the earth and on the waters motion is incessant. It may not be very rapid, but seldom is the air perfectly quiet. Sometimes it appears still on the surface of the earth, but the motion may be detected, by the clouds in the higher regions of the atmosphere. Though the winds vary greatly, yet the general direction is, in the temperate zones, from the equator to the poles. There is a general current passing between the warm and the cold regions of the earth, forming a circuit.

292. *The motion of the air attended by many admirable results.*

(1.) By winds the temperature of the earth is equalized. Were there no motion in the air, the heat in the tropics would become so intense, as to destroy every vestige of life; while the cold of the north would become so excessive, as to freeze every thing stiff. But by circulation of the air, the heated air of the south is carried to the cold regions of the north, melting the snows, unchaining the ice-bound rivers, and renewing vegetation; while, in the circuit, the cold air of the north comes down on the parched regions of the south, refreshing man and beast, and diminishing the intensity of the solar heat, which would otherwise burn up the very grass. We all know how greatly, in our own latitude, the temperature is affected by a south wind, on

the one hand, and a north, on the other; but we are hardly aware how much the distribution of heat is affected, and how great a portion of the earth, otherwise uninhabitable, either through excessive heat or cold, is rendered the delightful abode of man, by this cause.

(2.) The motion of the air causes rain. The waters evaporate from the ocean and from the surface of the earth, and remain suspended, in invisible vapor, in the atmosphere. The particles of vapor are so small, as to be borne up by the air. When, however, a current of warm and one of cold air meet, as they do in changing winds, the watery vapor in the warm current of air gives off its heat to the cold air, becomes condensed, and thereby increases in specific gravity, until, becoming heavier than its bulk of air, it can no longer be borne up, but falls in drops of rain. The magnitude of the drops of rain vary according to the rapidity of condensation, density of the air, and several other circumstances. If two currents of air, varying but slightly in temperature, meet, the watery vapor will be condensed in small atoms, and form clouds, or, if the air be very rare, the vapor will descend in the form of fog. There is no difference between clouds and fog. If we were up in the air in a cloud, it would appear only a fog. If there be considerable difference in the temperature of the meeting currents of air, larger drops of rain will be formed. If there be great difference, and one of the currents be freezing cold, hail will be formed. Snow is formed by the freezing of vapor.

Thus we see that to winds we are indebted for rain. The winds, however, must be variable, in order to produce rain. If they blow constantly in one direction, no effect is produced. This is the reason why, in some countries, it never rains. Cold and hot air is never mingled by the change of winds. In the temperate zones the winds are exceedingly variable—so much so, that the inconstancy of

the wind has become a proverb. Currents of air, of different temperature, are thus often mixed, and copious showers descend to refresh the face of earth.

The valley of the Wabash, in which the writer resides, seems to be a kind of battle-ground between the winds of the north and of the south. Here they seem to meet, and to expend their force on each other, neutralizing each other's action, and letting fall abundant waters. Our rains come not, as do those of New England, amidst high winds, but in a calm. Hence our climate is usually damp. The moisture of our climate, in connection with our long and warm summers, renders our vegetation surpassingly luxuriant and beautiful.

(3.) The motion of the air promotes the removal of moisture from the surface of the earth and from articles of human use.

A great variety of substances have to be deprived of all sensible moisture, before they are fit for the immediate purposes of life, or can be preserved for future use. Wood and lumber must be seasoned, before it can be used by the carpenter. Paint must dry, before the article on which it is spread can be used. A plastered room must dry, before it can be occupied without risk of health. Paper must be dried, before it can answer its purpose for writing or printing; and newly-washed clothes must be dried, before they can be safely worn. Newly-mown grass must be dried, before it can be preserved for hay; and sheaves of wheat must dry, before they can be thrashed. After long rains, or in the spring after the snows disappear, the earth must dry, before the farmer can work it.

Now, without motion of the air, these drying processes could never be carried on. Moisture can be removed from the surface of the earth, and from articles on its surface, only by being absorbed by air. The portion of air immediately in contact with the damp surface becomes soon so

saturated with moisture, that it can absorb no more. If, therefore, there were no motion of the air, the drying operation would soon be at an end; but, by the law of motion, before the stratum of air immediately in contact with the wet article becomes saturated, it gives place to another stratum, and that in turn to another, so that shortly all the superfluous moisture is effectually removed.

(4.) Without motion of the air the ocean, and lakes of the globe, and the rivers except with the current, would have remained unnavigable, at least up to the time of Fulton. Even now, with all the advantages of steam, how incalculably would the interests of commerce suffer, were the air to become once and for ever motionless! Indeed, it is doubtful whether, had not the currents of atmosphere for ages driven the ship over the waters, even Fulton or any body else would have thought of applying steam to navigation.

293. *Respirable properties of air.*—The phenomena of respiration we have fully explained. It only remains to notice, in this section, the design exhibited in diffusing air wherever a respiring being exists. We are surrounded, on every side, above, below, to the right, to the left, with the ubiquitous presence of the only element in which we can live. Were not the atmosphere respirable, all the other properties we have described would be utterly useless, merely from the want of this one, which is indispensable to living beings.

294. *Water.*—Water is composed of two gases—oxygen and hydrogen—in a state of combination. The proportions are, by weight, eight of oxygen to one of hydrogen; but so much lighter is hydrogen than oxygen, that, if we measure instead of weighing, there is twice as much of hydrogen as of oxygen.

295. *Fluidity.*—Hydrogen and oxygen, though both gases, become, on combination, fluid. The fluid condition

is more convenient than the gaseous or solid for the purposes of vegetable and animal life, but is not essential; yet, for the convenience of man—for his improvement in science and in wealth—this form is essential; for how else could commerce be carried on? By means of the fluidity of water the gallant ship booms over the sea from island to island, and continent to continent, bearing in its hold the products of earth and of art, whereby exchanges are made, and men enriched.

The fluidity of the rivers not only renders them navigable, but renders them subservient to man for purposes of manufacturing. It would have been a sad mistake, had the gaseous, as in the atmosphere, or the solid, as in ice, been the natural condition of water; and, had chance the disposing of this matter, such might have been the fact.

296. *Neutral properties of water.*—Water has neither color, nor taste, nor smell, nor any active property whatever. Its character is perfectly neutral. Had it been colored, it would have given its color to all substances with which it is mixed, and thus destroyed the variety of color now existing among bodies. Had it not been tasteless, it would give all our food its own uniform taste, which must have become unpleasant. Had it any active properties, its universal diffusion and use might have produced inconvenient effects.

It is remarkable that water should be neutral in its properties, when it is the only known combination of hydrogen with another gas that is not active. All the combinations of chlorine with hydrogen form powerful acids. Combinations of oxygen with any other gas than hydrogen are, also, more or less corrosive. Why, then, should this be an exception? Clearly because God, in his love, so designed it, and, in his wisdom, so accomplished it.

297. *Evaporation.*—Every body knows that, at a high temperature, water will boil, and escape in steam. This

steam may be again condensed into water. But water is constantly assuming a gaseous form, without the intervention of high heat. From the surface of ocean and of earth it is escaping, at ordinary temperatures, into the atmosphere. This is called evaporation.

It is a wise provision that, in evaporation, only the pure water—pure as if distilled—escapes. All impurities are left behind. The waters of the ocean are saturated with common salt; and they hold in solution, also, various other saline matters, rendering them wholly unfit for drinking or for vegetation; but the evaporation constantly going on, from every part of the ocean, carries into the atmosphere only the pure, simple, fresh water, leaving behind all the salt and nauseous compounds. For this reason lakes having no outlet usually become salt. All the water escaping from them going off by evaporation, leaves behind the saline matter, which accumulates through ages, and makes a salt lake.

Water evaporated from stagnant pools and filthy puddles leaves behind all its villanous compounds, and goes into the air pure and fresh. What a misfortune, had the law been otherwise! Had the water necessarily carried with it into the atmosphere, and then poured on the earth, the saline substances, the mineral matters, the impurities with which it becomes mixed in the ocean, and in lakes, and in pools, it would have been death to men, death to animals, and death to vegetation.

298. *Importance of evaporation.*—By evaporation the atmosphere is supplied with the materials for forming clouds and rain; and by rain alone the earth is supplied with materials for springs, brooks, and rivers. Vegetation might be sustained for a time without rain—by dew; but if there were no evaporation, there would be no dew. The only difference between rain and dew is this: when, at evening, the earth becomes cool, it condenses the vapor in the stratum of air immediately above the surface of the ground,

and that vapor is deposited on the grass and herbs in minute drops. In the same manner, if, at noon of a hot day, you place a pitcher of cold water in the room, the cold surface of the pitcher will condense the vapor of the surrounding air, and there will appear a deposit of mist on the pitcher. Rain, however, is caused by the condensation of vapor, not by the surface of the earth, but by currents of cold winds in the atmosphere; so that both rain and dew depend equally on evaporation, though the occasion of their reaching the ground is different.

If, therefore, there were no evaporation, there could be no rain and no dew; and without these the earth would become uninhabitable for men, or beasts, or plants. Many portions of the earth are now utterly barren, for the want of water. The great basin of the American desert, about the region of the great Salt Lake, needs only rains or irrigation to make it fruitful as the valley of the Connecticut. The burning deserts of Africa, and the barren plains of Asia, with a frequent and sufficient supply of showers, might be covered with vegetation. The desolate, treeless, herbless, and verdantless hills of Palestine might, by irrigation, become—what they once were—a land flowing with milk and honey. Without rains and dews, our own valley of the Wabash, now so beautiful—so teeming with exhaustless fertility—would become a parched and uninhabitable desert. Every river would cease to flow. Every stream would be dried up. Every spring would fail. Every man, and every animal, and every bird would die. The trees would be stripped of their foliage, the flowers would perish, the grass grow sear, the earth become parched and cracked, and every living thing would perish.

299. *Abundance of water.*—Some three-fifths of the surface of the earth is covered with water. The supply, therefore, is abundant.

Though every plant and every animal has been using

water from time immemorial, yet the supply originally manufactured by almighty Wisdom, and stored in the ocean, has not been sensibly diminished. Animals and vegetation do not annihilate nor distinctively consume the water they use. The form is for a time changed. The elements of water may become separated, in the stomach of an animal or the vessels of a plant. The liquid may become a solid or a gas; but the elements will again recombine. Pure water will be evolved from all animals and all vegetables. Water exhales from the leaf of every tree and the skin of every animal. The purifying processes of evaporation and filtration through the ground render the liquid, derived from whatever source, simple and fresh; so, there is as much now as there ever was, nor is there any danger that the supply will ever fail. It is true, some particular portions of the earth are badly furnished with reservoirs and rains, and some soils will not hold the water which falls on them. Some seasons of the year, too, are usually dry; yet, generally, water is furnished in abundance for all the purposes of men, of beast, and of vegetation. Like the air, it is free for all. Its supply and its facility of acquisition are commensurate with its indispensable necessity and universal demand.

What a wise provision, that these mineral substances—water and air—being indispensable to life, in any and every form, should be universally diffused, inexhaustible in quantity, and easy of access! Other minerals, not necessary to the sustenance of living beings, are more scantily furnished, and more difficult of obtainment.

300. *The solvent power of water.*—A solvent is any substance which has the power of comminuting any solid matter into indefinitely-small particles, and holding those particles scattered through the solvent substance, without generally occupying any room. Thus, water will dissolve salt, and yet occupy a smaller space than before. There are many solvents in nature. Most of the acids are solvents.

Generally, a solvent has active properties ; but water, though perfectly neutral in its nature, is one of the most extensive solvents. All the salts, alkalies, and most of the earths and metals are soluble, more or less, in water. To this property water owes its power of nourishing plants. The mineral matters which furnish the food of plants are dissolved in the water in the earth. The plants drink up the water by their roots, withdraw from it the matter in solution, and then exhale the pure water from their leaves. Were it not for the solvent power of water, trees could not, by any known means, obtain their nourishment. The solvent power of water gives it its purifying properties. It dissolves the filth of substances to which it is applied, washes it away, and then, by evaporation, filtration, and motion, purifies itself. The air, composed of oxygen and nitrogen, has no solvent power; but water, composed of oxygen and hydrogen, is almost a universal solvent; yet hydrogen alone nor oxygen alone has any such power. Why, then, should these two particular gases, in combination, have such power? No one has yet explained the physical reason why this is so. All we can say is, God pleased to have it so, because it was necessary to carry out his wise and benevolent purposes.

301. *Remarkable provision for preserving the fluidity of water.*—Water is naturally a fluid, but it becomes solid under a low temperature. It is only, however, shallow waters, or those in small bodies, which become frozen. The waters of the ocean never freeze, except in shallow bays, or in seas near the pole. Large lakes and rivers freeze only on the surface. Could rivers, lakes, and the ocean freeze solid, all animals living in the waters would die. Another fatal result would follow from the solid freezing of deep waters: when once frozen to the depth of the lakes and seas, the mass of ice could never be thawed. It is doubtful whether a body of water twenty feet deep,

frozen to the bottom, would thaw out, during the long and hot summers of this latitude.

Provision, therefore, must be made against the possibility of deep waters freezing; and this is accomplished by a most wise, most curious, and anomalous law.

Heat has the power of expanding all bodies. By increasing the bulk, the quantity of matter remaining the same, the specific weight is diminished. Thus, water, by being heated, rises. Mingling cold and hot water together, you will always find the hot at the top and the cold at the bottom of the vessel. The law of expansion generally is: the hotter the body, the lighter it is; and the colder, the heavier. When water is placed over heat, as particles at the bottom of the kettle become hot, they rise to the surface, and colder particles fall to the bottom—in their turn become hot, and rise to the surface; and thus a continual agitation and current is carried on, until the whole is heated, and boils. Freezing is the reverse of boiling. The particles on the surface of the mass of water, being in contact with the cold atmosphere, lose their heat, become heavy, and sink to the bottom. Warmer particles take their place at the surface, lose their heat, and sink in their turn. Water boils as soon as the whole mass becomes heated to two hundred and twelve degrees, and all boils at once. On the other hand, did it, in freezing, continue to cool off until the whole became cooled down to thirty-two degrees, it would instantaneously freeze solid. But large masses of water never get cooled down to thirty-two degrees—the freezing point—whatever may be the temperature of the air; and the reason is: water follows the general law of expansion by heat and contraction by cold, only to a certain, fixed, and invariable extent, and then reverses the law. When water arrives at the temperature of forty degrees, it has its maximum weight. Above and below that temperature it grows lighter. Thus, a particle of water at forty-one degrees and

one at thirty-nine degrees are each lighter than a similar particle at forty degrees. Now, suppose there is a lake of ten feet depth. The whole mass of water, in summer, may be of a temperature of from fifty to sixty degrees. As cold weather approaches, the water cools down. The surface portion is reduced from sixty to fifty-five degrees, and sinks to the bottom. Another portion at the surface becomes cooled, perhaps, to fifty degrees, and in its turn sinks. Particle by particle is cooled and sinks; and, if the process be continued, according to the general law, it would all cool down to thirty-two degrees, at which point it would freeze solid at once, and then the ice would get as cold as the weather might require; but when the water reaches forty degrees, it attains its maximum weight, and remains at the bottom. It cannot freeze at that temperature. That which cooled below that point becomes lighter, rises to the surface, and freezes; but the deeper water remains stationary, and cannot freeze, because its weight will not let it rise to the surface, so as to get cold. Now, how came water to vary at all from the general law of indefinite expansion, and of change of specific gravity by heat? and if it did vary at all, how happened it to follow the general law to a particular temperature, and then reverse it? and since it did reverse the law at a given temperature, how happened that temperature to be above the freezing point?

Has any philosopher or chemist ever attempted to show any reason, from the composition or nature of water or of heat, or from the laws of specific gravity, why water should be an exception to the general law, and an exception only to a particular degree? There is a reason—a final cause. It is this: the designs of the Almighty, in determining the relations between water and living beings, could not, so far as we can see, be accomplished in any other way than by subjecting water to this anomalous law. It seems to me, however, very much like a miracle. A general law is

reversed in a particular instance, at a particular point, for a special purpose. It differs from a miracle only in that the reversal occurs uniformly, whenever the particular element reaches the specific temperature. It is, therefore, a miracle repeated uniformly, whenever the conditions which first required it happen to exist.

302. *Water an indispensable element.*—Under the present constitution of nature, water is absolutely indispensable. The human body could neither be formed nor sustained without it. At least three-fourths, by weight, of the body is made up of water. Yet were it not a constituent of animal matter, it would be still necessary to life. Food could be neither cooked nor conveniently eaten without water. Nor could the simplest arts of domestic life be practiced. Bread could not be made, nor coffee nor tea prepared, nor the essence of herbs extracted, nor garments washed. To carry on manufacturing operations, animal force alone could be applied; for not only would the wheels of the water-mill stop, but even the steam engine would be useless without water.

303. *Heat.*—Of the nature of heat we know little or nothing. Whether it be matter or a quality of matter, we cannot tell. But while we know nothing of the nature of this most important agency, we thoroughly understand its law; and herein are we to look for illustrations of the divine wisdom and goodness.

304. *Expansive power of heat.*—We have already noticed the expansive power of heat, so far as water is concerned. But the importance of this property requires a more extended notice.

Were it not for the expansive power of heat, the bodies of men would become as stiff as Lot's wife. The trees would assume the hardness of stone coal. The waters would be crystals of ice. The soil of the earth would be solid rock; and every living being would become a statue

of petrification. Were it possible for men and animals to exist in such a condition, yet no art could be practiced. The metals could not be wrought, rocks could not be blasted, chemical compounds could not be mixed, and food could not be cooked. Were heat not expansive, the entire material universe would be as different from what it now is as it is possible to conceive.

Why should heat have the power of softening iron, melting ice, keeping the atmosphere fluid, expanding water into steam, and of effecting a thousand other things by its expansive agency? Can any one show, from the chemical or physical nature of heat, that such a power was necessary? No one has ever attempted it. God, in his own good pleasure, for wise and benevolent purposes, gave heat this property as a special endowment.

305. *Conduction of heat.*—Heat is susceptible of being conducted from particle to particle of matter, and thus diffused throughout the entire substance. But there is a great difference in the conducting power of different bodies. Iron and, indeed, most of the metals, conduct it readily. If you place one end of an iron rod in the fire, or one end of a brass pin in the lamp, and hold the other end in your fingers, you will soon find the heat so diffused through the rod or pin, as to compel you to drop it. But you may hold a wooden rod in the fire until the exposed end is utterly consumed, without feeling any heat at the end you hold. This is owing to the difference in the conducting power of the bodies—metal and wood.

Having made this explanation, we shall look for evidences of wisdom and love in the relations between the conducting power of some of the common and well-known substances, and the purposes for which these substances are designed.

306. *The metals generally good conductors.*—To the property of conduction metals owe their susceptibility of being drawn out into rods and wires, and hammered out by the

smith into tools. Place a piece of iron in the fire, and, by means of its conducting power, all its parts become equally heated. It grows soft and malleable. It may then be hammered into any shape, and fashioned into an ax, or a knife. But if you place glass in the fire it will, owing to its bad conducting power, expand unequally, and break; nor can you hammer it into shape. Now, if iron had only the conducting power of glass, it would be impossible to render it serviceable to man in the shape of tools. True, you might melt it as you may glass, and blow it, or mold it into shape, but then it could not be tempered, and brought to a cutting edge. It would be so brittle, that every smart blow would break it. If, therefore, iron had only the conducting power of glass, we should have to resort to the stone chisels, and flint axes of the earlier savages, and all the mechanical improvements of modern times would be knocked into non-entity.

307. *Water has no conducting power at all.*—It can be heated only by a change of place among its particles. You may build a fire, hot as Nebuchadnezzar's furnace, on top of a kettle of water, and let it burn for ever, and the water would not boil. Not a drop of water gets hot, unless it touches the hot surface of the kettle. It can receive heat from other bodies, but it cannot diffuse that heat through its own mass, except by motion. Now, if water could conduct heat like iron, then when a deep lake becomes so cooled that the water at the bottom is at forty degrees, and that at the surface at the freezing point, the heat from the deeper water would be gradually conducted away through the surface, and the whole would cool down below the freezing point, and by this means the wonderful provision explained in section 301 would be defeated. The law of expansion by heat might still continue reversed, as we have explained in that article, but still the law of conduction would defeat the whole plan. So we see, that had not the divine Wisdom,

when he reversed the law of expansion to prevent deep water freezing, at the same time have made water a non-conductor of heat, he could not have accomplished his benevolent design. But there is no oversight, no mistake in the plan. The relations between heat and water, two entirely-dissimilar substances, are perfectly adjusted.

308. *Air is a non-conductor.*—It can be heated only by absolute contact with some warm body. This is a wise provision, as we shall see.

(1.) If air were a conductor of heat there would be neither winds nor currents of air. If when a particle of air becomes heated, it could communicate that heat to its neighbor, the whole mass of atmosphere might become heated equally, without motion, like a piece of iron. Hence, all parts being equally heated, there would be no displacement, no currents, no motion—all the advantages described in section 292 would be lost.

(2.) If air were a conductor of heat the cold of the polar and even of the temperate regions would be wholly insupportable by man and animals. In a quiet atmosphere, the air immediately in contact with the body becoming warm, and retaining the heat through want of conducting power, invests the body with a protecting barrier against the extreme cold of the climate. But let the heat of the stratum surrounding the body be conducted to the adjoining strata, and the heat would be abstracted from the body so rapidly as to produce death. We all know that on an open prairie, exposed to an incessant current of wind, a man will perish with cold much sooner than in a sheltered position, though the temperature of the two places, as indicated by the thermometer, be the same. But a calm atmosphere conducting heat would have the same effect as a windy current. In a conducting atmosphere the same stratum would constantly be abstracting heat; and in a windy one moving strata carry it off. You have read the fable of the

fox and the swarm of flies. A quiet atmosphere conducting heat would be like the same swarm of flies, disgorging the blood as fast as they absorb it, and therefore constantly hungry. The fox would as soon choose a new swarm, as the same old one never satisfied. It is a remarkable fact, that in high northern latitudes, during winter, the air is uniformly quiet. We should naturally suppose violent winds would blow incessantly in polar regions; but they are much less frequent and boisterous than in the temperate zones. This fact, taken in connection with the non-conducting property of air, renders man and animals less liable to suffer from the intense cold of the frigid zones, than from the warmer but windy atmosphere of more southern latitudes.

309. *Fur, wool, and feathers non-conductors.*—The covering of all animals of cold climates is a bad conductor of heat. Compare fur with silk, woolen with cotton, and feathers with linen, and you will at once appreciate the difference in warmth. But this difference is wholly owing to the fact that woolen, and fur, and feathers, are bad, and silk, and cotton, and linen, are good conductors of heat. In cold climates it is necessary, for the protection of the animal, to clothe it with such material as shall keep the animal heat from escaping too rapidly, and this is admirably effected by the use of bad-conducting substances.

310. *Snow a bad conductor.*—It is a wise provision, that snow is a poor conductor of heat. Were it otherwise, vegetation in northern climates would inevitably perish in winter. The ground would freeze to a depth defying the summer sun to thaw it out. But the non-conducting covering of snow protects the earth beneath from frost, and preserves the roots of trees and the buds of herbs and grass from injury. When in northern latitudes snow falls early in winter, before the naked ground becomes frozen, the earth remains unfrozen all winter, however cold, and the grass appears fresh and green under the snow. The snow

is therefore a blessing to the north. Did no more snow fall in Maine than in Indiana, the winter of Maine would be fatal to most kinds of perennial vegetation.

311. *Radiation of heat.*—Heat not only passes by conduction from one particle of matter to another in contact, but it is also sent out through space to a distance from the calorific source. You may see this exemplified before a burning fire, in the heating of a piece of wood or metal, placed some distance from the fire. You also feel the heat when you stand near the fire. This passing of heat through space is called radiation. It is an important property. By radiation the heat of the sun reaches the earth. By radiation in summer the heat received from the sun by the earth through the day passes off into the atmosphere by night, preventing thereby an inconvenient accumulation.

In winter, when radiation from the earth would produce too intense cold, it is prevented by snow. It is greatly obstructed by clouds, mists, and fogs. This is the reason why, in summer, cloudy nights are more oppressive than clear, and why mists and vapors rising from rivers over low lands protect the crops from frost.

312. *Radiation modified by color and surface.*—It is a well-known fact that heat will radiate from a body of dark color and rough surface, much more readily than from one of bright color and polished surface. A rough stove gives out more heat than a polished one. An earth-colored vessel filled with hot water cools quicker by radiation than a white porcelain. Heat radiates from the animal body through a dark dress more readily than through white clothing. We see from these facts the reason why God has given most animals of the north, as the bear and the rabbit, not only a thick but a light-colored coat, and why some northern animals change in autumn from brown to black, and why snow is white instead of black. In all these cases the design of the light color is to keep the heat from radia-

ting too freely into the atmosphere. The design is benevolent, and the execution wise.

313. *Sources of heat.*—The sources of heat are natural and artificial. Heat from natural sources, as the heat of the sun and animal heat, can neither be produced at will, nor increased, nor diminished by man. But heat from artificial sources, as from friction, combustion, and chemical combination, is always at his command, coming and going at his bidding—ready at his call, and subservient to his will.

And in this provision for artificial heat we see evidence of great benevolence to man. The veriest savage can kindle a fire, wherever fuel can be found, to warm him and cook his food. The smith can raise in his forge heat to render iron pliant and steel malleable. The founder can melt the iron and the brass, and mold it into any shape he pleases. The engineer can raise his steam to drive the machinery for manufacturing, or the car over the iron track, or the ship over the waters. The chemist can raise at will a heat sufficient to melt the hardest substances of nature—a heat exceeding two hundred times that of boiling water—thereby enabling him to analyze the elements of nature.

It requires scarcely a remark to call the attention of the most careless observer to the inestimable value of the power given to man of producing, controlling, and using artificial heat.

LECTURE XII.

ADAPTATION OF THE METALLIC AND EARTHY MINERALS TO THE WANTS OF MAN.

Minerals—Form of minerals—What we mean by design—Design in mineral forms—Of the metals—Iron—Properties of iron—Other metals—Poisonous metals—Design of poisons—Accessibility of metallic ores—Earthy minerals—Disintegration—Qualities of a good soil—Properties of silex—Used in making glass—Properties of alumina—Plastic property—Brick—Slate—Earthen-ware and porcelain—Mineral or artificial teeth—Alum—Porphyry—Lime—Chalk—Marble—Phosphate of lime—Fluate of lime—Sulphate of lime—Hydraulic lime—Chloride of lime—Common limestone—Quicklime—Gems and precious stones—Crystalization.

314. *Minerals.*—The term mineral, as used in works of science, includes all inorganic substances. Hence, every thing not capable of exercising living organs is a mineral. In this sense water and air are minerals. But in this lecture we shall use the word in a more restricted and popular sense, appropriating it to such substances as are usually dug out of the earth. We shall, however, by no means even name all of the endless variety of mineral substances, but shall select a few of the most common and most important metallic and earthy minerals, and exhibit the adaptations of their most obvious and characteristic properties to the physical nature and the wants of men.

315. *Form of minerals.*—In section 17 we remarked, that though regularity of form is one of the characteristics of inorganic substances, yet no design in their forms is evident. We mean by this remark, that, so far as we can discover, the mineral could just as well exist in a shapeless as in a regular form. We may add in this connection, that, so far as mere use is concerned, we know of no advantage to man to be found in the regular form of minerals. It is true, crystals are beautiful, and the contemplation of their beauty, as well as the beauty of flowers, improves the intel-

lectual and moral tastes of man. Gems and precious stones may owe a portion of their value, as articles of ornament, to their regular form.

We must not, however, conclude that there can be no useful and benevolent design in crystalline forms. The universal law of crystalization is, probably, intended to answer some purposes of good not yet discovered.

316. *What we mean by design.*—We should, perhaps, in this place explain the different senses in which we use the word design. We generally imply by *design* the final cause, end, or purpose in view, or the reason for which a thing is done. We also sometimes use the word as implying intentional, in opposition to accidental acts. A man is said to do a thing *designedly* when he meant to do it.

317. *Design in mineral forms.*—Now, in this sense, there is design most incontestably exhibited in the regular and crystalline shapes of minerals. The regular forms of minerals are not the result of accident. They are the result of specific and systematic law. If they were the result of accident, we should find all kinds of substances occasionally presented under every possible variety of form. But observation proves, that any particular substance, as iron, lead, and lime, has each a primary form, to which it may be by simple cleavage always reduced. Carbonate of lime, for example, may occur under a great variety of secondary forms; but the cleaving knife will in every case easily reduce all to one and the same form—a rhomboidal solid. Though there is in some minerals considerable variety in secondary forms, yet is their number fixed and limited. The mathematical accuracy of the angles of crystalline substances precludes all idea of accident. No carpenter can possibly shape a piece of wood into a cube or prism so perfect, their faces meeting at such invariable angles, as nature has given to the minerals of the earth. In identical compositions, and at equal temperatures, the faces of the crystal meet at

angles absolutely invariable. Not the nicest instrument can detect the slightest departure from perfect uniformity. Pure carbonate of lime invariably crystallizes at an angle of $105^{\circ} 5'$; pure carbonate of magnesia at $107^{\circ} 25'$. Now, if carbonate of lime and carbonate of magnesia combine together in a given proportion, and the composition crystallize, the angle of crystallization will vary from that of the pure specimen in proportion to the amount of each element entering into the composition. If equal quantities of the elements enter into the composition, the angle of crystallization will be half way between that of the two elements. In the particular specimens before us we should have,

$$\frac{105^{\circ} 5' + 107^{\circ} 25'}{2} = \frac{212^{\circ} 30'}{2} = 106^{\circ} 15'$$

for the angle of the composition. If ten times as much lime as magnesia entered into the composition, we should have,

$$\frac{105^{\circ} 5' + 10 \times 107^{\circ} 25'}{11} = 105^{\circ} 17' 43''$$

as the exact angle of the composition crystal. The law is general—uniform—never varying. It is so constant, that if we measure the angles of any crystallized specimen, we can tell whether it be pure or not. And, if not pure, we can tell what foreign substances enter into it, and in what proportions they exist. If we know the angles of any number of separate specimens, and then mix them in known proportions, and crystallize them, we can determine beforehand the angles of the crystal.

Can such uniform regularity, such unvarying constancy, exist without intention and design? The facts prove, not only that there is a designer, but that there is but one. God is one in nature, as well as in revelation.

May it not be, that the regularity, order, system, and beauty exhibited in the mineral world, is designed as an indication of the conformity to right, the harmony of action, and the beauty of perfection, which God desires

in the moral world? In the mineral world there are many irregularities of form—wide departures from the perfect standard—many deformed and monstrous shapes. But these are the result of disturbing causes. There was some mechanical obstruction, some foreign interference, so that the crystalizing materials could not act freely and naturally. These deviations from the standard are no evidence of want of design, but they show that the execution of the design in its details was left subject to the influence of secondary causes.

In the moral world there is much depravity, disorder, and sin. These evils are the result of disturbing influences, interfering with the execution of the perfect and righteous law of morality, according to which God intended every specimen of human character to be molded. Amidst all the imperfections of human character, the design of the almighty Creator is still evident—the law is clear and explicit—the standard is held up—the intention is manifest. Both in the mineral and in the moral world God suffers and permits departures from the standard of perfection, without at all detracting from his own glory, as a powerful, wise, good, and perfect being.

318. *Of the metals.*—We shall neither name nor describe the numerous substances called metals. They are sufficiently well known to the general reader, for the purposes we have in view in these lectures. We will select from the extensive class one individual metal—iron—and call your attention to such of its general and characteristic properties as contribute to adapt it to the wants of man.

319. *Iron.*—Iron is more abundant than any or all other metals. It is disseminated through the soil, and in nearly all the rocks on the globe. The rocks on the surface usually owe all their varieties of color to some modification of iron entering into their composition. It is found in veins, in beds, and in large mountains. Its universal dissemination

is evidently designed. Not only is it needed everywhere for purposes of art, but it enters largely into the composition of animal bodies, and is found in vegetables. For the reason that it is universally necessary, it is universally diffused.

320. *Properties of iron.*—By being naturally solid, iron will retain the shape in which it may be put for purposes of art. By its fusibility, it may be rendered liquid and molded into innumerable shapes, answering important purposes for manufacturing machinery, and for cooking vessels. By its power of conducting heat, it is admirably adapted to every purpose of boiling. By its ductility, it may be drawn into wires of any degree of fineness for innumerable useful purposes. By its malleability, it may be hammered into any shape desirable to man, furnishing him every variety of edgetool. The susceptibility of steel, which is only a preparation of iron, of being hardened to any degree, and thereby acquiring the power of retaining a sharp, cutting edge, is of vast importance to man. It would be useless to undertake to enumerate the endless variety of instruments of modern invention, owing all their value to this property of steel. Another invaluable property of iron is its magnetic susceptibility. Other substances may possess this property in a slight degree, but iron only is adapted to the purposes of the magnetic needle. All attempts to convey in language an adequate idea of the inestimable value of the magnet, would be useless and hopeless. Without it no mortal being would dare attempt to cross the Atlantic, or hardly to venture out upon our own lakes.

Suppose, now, iron either irrecoverably annihilated, or its properties of ductility, fusibility, malleability, temperization, and magnetism destroyed or changed: to what a sad condition would civilized society be reduced! In agriculture and manufactures we must go back to savage life; and, as for commerce, it would be annihilated—absolutely annihilated.

We might burn up our ships, for they would never venture out of sight of land. We might, it is true, follow a coasting trade from city to city; but even that would be dangerous—far more dangerous along the stormy coasts of the Atlantic than it was in ancient times along the inland shores of the Mediterranean, or over the quiet waters of the *Ægean*.

We may reasonably ask, how iron, so abundant and cheap, came to possess so many, so various, so independent properties—properties without which the arts of modern civilized life could not exist. There can be found no natural necessity why iron should be malleable and magnetic, any more than glass; but God wisely and kindly to man ordered it so, and it is so, and so it will ever remain, unless he, for wise and good reasons, should miraculously order it otherwise.

321. *Other metals*.—We will merely mention some of the characteristic properties of other metals—properties to which they owe their value to man: the fluidity of quicksilver, rendering it suitable for the barometer and thermometer; the easy fusibility of tin, its illiability to rust, and its destitution of poisonous qualities, all rendering it suitable for forming a coating on sheet iron, for domestic utensils; the high degree of malleability of gold, and its remarkable power of resisting the action of the air and other agents which tarnish the common metals—qualities rendering it valuable for purposes of ornament; and the high power of resisting heat characterizing platinum, it yielding to fusion only at a heat two hundred times as high as that of boiling water, thereby rendering it of invaluable service to the chemist for vessels for melting substances at a high heat.

322. *Poisonous metals*.—No metal, not even arsenic, is poison in its pure, metallic state; but when combined with oxygen, or, in common language, rusted, copper, lead, and many other metals become poisonous. The poisonous qual-

ities of these metals detract greatly from their value in domestic economy.

323. *Design of poisons.*—Nor may we be able to detect the design of these poisonous properties. At the risk, however, of being read out of the books by the doctors, I will make a suggestion. I believe all vegetable and mineral poisons are designed for medicines. Not only are all poisons medicines, but all medicines are poisons. When taken into the animal system under proper circumstances, at proper times, and in proper quantities, they act as medicines. When administered under improper circumstances and in improper quantities, they act as poisons. God has given the lower animals instinct to teach them when to use and when to refuse medicinal, or poisonous substances. He has given man intelligence and reason, by which he may and should discover the uses and abuses of all natural productions. If we, therefore, get poisoned, it is our own fault, or the fault of others—in all cases to be imputed to our ignorance. We each ought to know the medicinal qualities of all articles of daily use. Physicians are bound under moral obligation to know all about the medicinal qualities of every accessible and procurable vegetable and mineral substance.

324. *Accessibility of metallic ores.*—Metals, as a class, are heavier than the average of known substances on and near the surface of the earth. If the earth, as geologists believe, and as facts indicate, were once a liquid mass of melted matter, the metals would, by their great specific gravity, cluster about the centre. In that position they would be inaccessible to man. To bring them within man's reach, the crust of the earth has been broken, and its strata upturned, in many instances, at an angle of ninety degrees, so that substances from great distances beneath the surface are now brought in open sight. In many instances metallic ores have been thrown up to the surface in veins by v-l-

canic action. By these means metals, otherwise for ever inaccessible to man, have been brought into a position from which the miner may easily draw them for the purposes of life.

In the works of God nothing is overlooked. No part of the scheme fails for want of foresight. Valuable minerals are not made, and then left in inaccessible places. They are brought into positions in which they may be obtained with only the moderate labor necessary for the physical and moral improvement of man.

325. *Earthy minerals*.—Of what are usually called earths there are three which, from their abundance and value, require to be particularly noticed. These three are silex, alumina, and lime, or, to use the names commonly appropriated to them, sand, clay, and lime. These three substances form at least nine-tenths of all soils and all known rocks on the globe.

326. *Disintegration*.—Silex, alumina, and lime, unquestionably, originally existed only in solid rocks. Silex was imprisoned in flint and in granite, alumina in slate and granite, and lime in solid limestone and marble; but God made these solid rocks capable of easy disintegration. The action of water and of frost is sufficient, in the course of time, to wear away the stones, and comminute them to fine soil. In this way, and this way only, soils have been formed. The theory that God made the soils of the earth just as they are, and just where they are, no man, who has carefully examined the subject, would propose or defend. He made the substances of the earth fluid; they hardened into ledges of rock, and then wore and crumbled to soil. Water and frost have been the chief agents in this process. The agency of frost is very powerful. Let there be the slightest crack into which moisture can insinuate, and the expansive power of frost will heave the rock asunder. Just dig up, in autumn, a quantity of earth, and

leave it on the surface. No matter how hard it is, if it be at all pervious to water, the frost of winter will make it as fine and mellow as a heap of ashes. Had there been no deluges and currents of water to disturb and displace the natural soil, in every place the soil would be of the same elementary and mineral character as the rocks below it; but scarcely a spot can be found on earth where deluges and currents have not been active, removing the original soil, and leaving a deposit of foreign ingredients.

327. *Qualities of a good soil.*—A good soil consists of a proper mixture of sand, clay, and lime. If there be too little sand, the soil is wet and heavy. If there be too little clay, it is too open and dry. If there be too little lime, the grains and grasses, most of which contain lime in their composition, cannot flourish for want of their appropriate nutriment. Vegetable mold, animal remains, and various alkalies and salts enter, in quantities greater or less, into most soils; but the quantity of these is always very small in proportion to the lime, sand, and clay—much smaller than is generally supposed. In the most soils you will find, by careful analysis, not over one-tenth of the mass composed of vegetable and animal matter.

Both silix and alumina, as well as lime, enter into the composition of plants. Wheat consists of nearly one-half silix, three-eighths lime, and the rest alumina. Oats consist of two-thirds silix, one-fourth lime, and the rest alumina. Clover consists of three-eighths silix, one-third lime, and the rest alumina. It should be recollected, however, that, in addition to the silix, alumina, and lime, there are, in most plants, minute quantities of other earths, of various salts and alkalies, but of them no account is taken in the analysis from which these results are derived.

As a general thing, a good soil should consist of about one-half sand, one-third lime, and the rest clay and miscellaneous matters.

In some parts of New England the soil is either nearly all clay or all sand, and of course unproductive. In other localities there is a better mixture. Lime, however, is generally deficient in the New England soils, and therefore wheat fails. In the Wabash valley there is an admirable mixture of fruitful ingredients, and we have the most productive soil in the world. Very little of the fertility of our soils arises from vegetable remains. Give us a farm whose soil consists of sand, lime, and clay, well mixed, and we ask no more for agricultural purposes.

328. *Properties of silex.*—The best specimen we can get of pure silex is a good flint, or a piece of quartz, usually called rock crystal. Let this be comminuted or ground up by any means, and you would have pure sand. It is incombustible, for the reason that it is already saturated with oxygen, and of course cannot undergo combustion, which is only a rapid combination of a body with oxygen.

329. *Used in making glass.*—But, though incombustible, silex is not infusible. Mixed with potash, it melts, and makes glass. This is a remarkable, a curious, and an important property. The same substance, which is now a flint, and now a mass of fine sand, again becomes clear, transparent glass. A common earth, cheap as dirt, is endowed by the almighty One with a property, by means of which we may convert it into one of the most interesting and valuable products of arts. For, to say nothing of the use of glass for windows, and for drinking vessels, to how many scientific and philosophic purposes is it applied! Without glass the evils of short-sightedness, (§271,) and the defective vision of age, (§272,) could never be remedied. Without glass the barometer and the thermometer could never be used. Without glass the microscope would never reveal the existence of animalculæ, nor the telescope bring to light from the depths of space planets, and stars, and worlds, unknown and unnumbered.

330. *Properties of alumina.*—We have already seen that alumina is an essential constituent of all productive soils. It is the basis, the chief ingredient of all clayey soils. When excessive in the soil, even when not exceeding one-half the mass, it renders the soil liable to bake and crack in the sun, thereby becoming unsuitable for productive vegetation. But the very property of alumina which renders soils excessively aluminous unproductive, contributes incalculably to promote the arts of civilized life.

331. *Plastic property.*—The property referred to in the last section is that of forming with water a plastic mixture, which may be easily molded into any shape, and by heat hardened to any degree.

332. *Brick.*—The propensity of animals to provide habitations to protect themselves from aggression and from the vicissitudes of the weather is instructive. The little ant erects its earthy mound, the "foxes have holes," the bear seeks out a shelter under some fallen tree, or projecting rock, the beaver builds a habitation in ingenuity and convenience vying with the human, and the domestic animals, from the barn-yard fowl to the horse, attach themselves to the home provided for them by man.

Man, in every clime and in every age, exhibits the influence of the same instinct, terminating in civilized life in the highest triumphs of reason and of art. The varieties of human habitation, from the rude tent of Abraham to the glorious temple of Solomon, the house of God; from the mud huts of the Nile to the structures of hundred-gated Thebes; from the rocky caves of the ancient Pelasgi to the classic Parthenon; from the thatched cottage of the ancient Briton to the palace of the English nobleman; from the log cabin of the western pioneer to the ornate cottage of New England or the splendid mansions of the Hudson, mark the origin, progress, and degree of civilization. Materials for

building thus appear of great importance in the economy of life. One of the cheapest, most convenient, most permanent materials is easily manufactured by the simple mixture of water and clay. Take up anywhere, within twenty miles of the spot where I am writing, any portion at random of the soil, mix it with water, mold it into convenient shape, and let it dry in the sun, and you will have a valuable material for building you a house. If you desire a more ornate and lasting material, place your molded clay in a kiln, kindle under it a fire, and you have elegant brick.

333. *Slate*.—For covering the roofs of dwellings, invaluable for that purpose in a city exposed to fires, and nearly imperishable from exposure to the weather, God has formed in natural brick-kilns inexhaustible quantities of slate, which is nothing more than clay hardened by heat. Mold clay into shape, and heat it in the open air, and you have brick. Mold it into shape, and heat it under the pressure of water, and without the presence of air, and you have the common slate. Quarries of slate are found in immense quantities in Europe and in America. There is enough in the valley of the Penobscot river, in the state of Maine, to slate over all the cities of the globe. Whoever examines with a scientific eye its structure, as exhibited in its native localities, must be convinced that it was formed by the hardening through volcanic heat of thin layers of clay, under the pressure of superincumbent waters.

334. *Earthen-ware and porcelain*.—Common clay molded and burnt, forms all the varieties of crock, and jug, and milk-dish, and whatever else is usually called pottery and stone-ware.

Finer kinds of clay, more purely aluminous, molded and burnt, form all the varieties of crockery, queensware, China-ware, and porcelain.

The varieties of aluminous or argillaceous ware contain

different proportions of silex mingled with the alumina, but the plastic property, by means of which the material is molded, is wholly owing to the alumina.

335. *Mineral or artificial teeth*.—The best material which dentists can obtain for manufacturing artificial teeth is a composition whose principal ingredient is alumina. The teeth manufactured of this substance are of a superior quality, having the requisite hardness, neatness, and durability.

336. *Alum*.—Alumina, combined with sulphuric acid and potash, forms alum, a well-known and very useful substance, without which the valuable art of dyeing could not be successfully prosecuted. There are many colors which will not adhere to the texture of cloth without the intervention of what is called a mordant; and in most cases alum forms the mordant.

We thus see to how great variety of uses this common and abundant earth is adapted. As we have before remarked, (§15,) it does not enter into the organization of animal bodies. Man, though formed of dust, is not literally made of clay. At least no trace of alumina has been detected by analysis in his composition.

337. *Porphyry*.—The celebrated porphyry of the ancients is an aluminous rock. The ancients applied this name to all rocks of a *purple* color, and hence it includes specimens of a great variety of composition. But all varieties contain feldspar, or some other aluminous mineral, either as the base, or as crystals of various sizes interspersed and disseminated in the body of the rock. The Egyptian porphyry is the most elegant of all ornamental stones. Its excessive hardness renders it expensive for the moderns to work. By what means the ancients succeeded in working it into so many and elegant forms we know not. The art of cutting it seems lost.

338. *Lime*.—The natural condition of lime is in solid

rock. It is usually called limestone. Chalk and marble are only varieties of limestone. The only difference between common lime rock and the finest marble consists in different degrees of crystalization. The constituent material is precisely the same. The colors of limestone and of marble are owing to the mixture of various quantities of iron and manganese. We will notice the properties and uses of the most interesting varieties of lime.

339. *Chalk*.—Chalk seems to have been formed by the hardening, by heat, under the pressure of superincumbent water, of limestone reduced to a condition much resembling paste. By this process it assumes a friable nature, adapting it wonderfully to the well-known uses to which it is applied. No other form of lime can be used to advantage for this purpose.

340. *Marble*.—Marble was formed by the crystalizing of fluid limestone, probably under the pressure of water and the influence of high volcanic heat. It is plentifully found in various parts of the world. It owes its value in the arts to the elegant polish it receives, and to the ease with which it is worked. It is admirably adapted to architecture, statuary, and monumental works. It thus furnishes an imperishable protection for the living, and transmits to posterity the memory of the dead.

341. *Phosphate of lime*.—This substance, as we have already seen, enters largely into the composition of animal bone. It seldom occurs in minerals. I have found small specimens disseminated in granite ledges in only one locality—a small island in the Penobscot Bay. It seems created almost exclusively for the purpose of making bone.

342. *Fluate of lime*.—This is usually called fluor spar, or Derbyshire spar. It is one of the most beautiful of mineral substances, capable of the highest polish, and may be worked into any form for vases and ornamental articles.

343. *Sulphate of lime*.—This variety is called gypsum,

plaster, and plaster of Paris. The finer kinds are called alabaster. It occurs abundantly in nature. The most noted quarry is in the neighborhood of Paris. It has the property, when slightly burned, of being reduced to paste in water. In this condition it may be molded into any shape, and casts may be taken with it, and it may be worked into fresco walls, or any other ornamental finishing. When the molding or plastering is finished it dries hard and firm.

The coarse gypsum from the quarries is often ground up in a mill and used by farmers for enriching the soil.

344. *Hydraulic lime*.—This variety, when made into mortar, has the property of hardening under water. It is called hydraulic cement. It is invaluable for the construction of cisterns and reservoirs. It is frequently used to cement stones and gravel beneath the water of rivers and harbors, to form foundations for piers and marine structures.

345. *Chloride of lime*.—This variety is used extensively for bleaching, and for purifying various localities of villanous smells.

346. *Common limestone*.—The common limestone consists of pure lime combined with carbonic acid, and thence called carbonate of lime. To reduce it to a condition useful for purposes of cement in masonry and plastering, the carbonic acid is driven off by heat. Were the rock as quarried from the ledge incapable of being reduced to quicklime by heat, it never could be made into mortar. In New England they burn it some nine days in a kiln. In the west they erect a huge heap of logs, place a small quantity of lime rock on the pile, and set fire to the mass. When the heap burns down, the lime is ready for slacking.

347. *Quicklime*.—Carbonate of lime burned until the carbonic acid is expelled becomes pure lime, and is called quicklime. The most remarkable property of lime in this state is that of combining chemically with a large quantity of water. It is not a mixture, but an actual combination

with water. The water becomes combined in a solid form with the lime. During the process intense heat is generated. In chemical combinations heat is always generated when a fluid is changing to a solid, or even when a gas is undergoing condensation. The heat of slacking lime is thus produced, by the water giving out its latent heat in passing from a liquid to a solid.

When the lime becomes saturated with water, it falls into a light, fine powder. By the mixing of sand and water with it in this condition, you form the well-known mortar of the masons.

We thus see the variety and value of the uses to which lime is applied. Is it not wonderfully curious, that the same substance should be applicable to such a variety of purposes? Surely it manifests great economy of means and comprehension of plan in the Author of nature.

348. *Gems and precious stones.*—In our notice of the properties and uses of these common earths, we have said nothing of the precious gems, of which they constitute the chief, and in some instances the only important ingredient. The chrysoberyl, hyacinth, chrysolite, sapphire, topaz, opal, ruby, emerald, amethyst, garnet, tourmaline, jasper, and chalcedony, the most beautiful gems of earth—so precious as to be used by the Almighty for garnishing the foundations of the walls of the New Jerusalem—are made up entirely of silice and alumina, with a slight admixture of miscellaneous ingredients, introduced merely for coloring.

349. *Crystalization.*—How wonderful the process by which mere common dust is transformed into costly pearls and precious gems—sand and clay into ruby, topaz, emerald, and opal—and, what is still more surprising, charcoal into diamond! In looking at the wonderful results of the laws which God has imposed on nature, man must wonder, admire, and adore, but he cannot imitate. He knows precisely of what materials, and in what proportions thereof,

the diamond is composed, but all his ingenuity and art fail to make it.

We have thus noticed the most striking properties of only one of the metals, and three of the earths. There are innumerable other metallic and earthy substances, each of which might furnish useful lessons of instruction; but it is our purpose only to present a few, out of the many works of nature illustrating the attributes of the Deity. There are, however, a few other substances usually classed as minerals, which we cannot well pass by without a passing notice.

Common salt is found in inexhaustible quantities in mines, and easily obtained from springs, lakes, and the ocean. We have said (§212) that no animal can live on mineral matter. And yet all animals eat salt, and, probably, man and many quadrupeds would die without it. Though we eat salt, yet it does not probably enter into the organization of any animal tissue. It is always found in the blood, and in most of the excretory fluids formed from blood. Dr. Prout, in his *Bridgewater Treatise*, suggests that its presence in the blood is essential to maintain the blood in a fluid state. At any rate, though salt be not a constituent of animal tissue, it is essential to animal life, and God has, therefore, abundantly furnished it in nature, and given man and various other animals an instinctive craving for it.

350. *Coal*.—Though coal is unquestionably of vegetable origin, yet we may without impropriety notice it as a mineral, inasmuch as, however it may have been originally produced, it is now found like minerals in the earth.

Coal is furnished by nature inexhaustible in quantity, and accessible in position. It is also indispensable for man. It is not known how the manufactories and many of the arts of life could be carried on, even now, in many parts of the world, were it not for coal. The wood with which the

earth is naturally covered in most places, soon disappears in thickly-settled countries, and without coal there would be nothing to supply its place.

It is an interesting consideration, that long ago, thousands of years before man was created, coal was laid up in exhaustless stores for his use, in order that when the wood, which was designed for his accommodation in early time, should be consumed, the coal might be brought to light, adapted to all the purposes of fuel.

LECTURE XIII.

RELATION AND ADAPTATIONS OF THE EARTH TO THE CONSTITUTION AND WANTS OF HUMAN BEINGS.

Shape of the earth—Irregularities of surface—Origin of inequalities of surface—Advantages of uneven surface—Effect of beauty and sublimity of scenery—Distribution of land and water—Geographical location and shape of the continents, islands, and seas—Motions of the earth—The seasons—Constancy of climate—Relations between the length of the year and the constitutions of plants—Diurnal motion of the earth.

351. *Shape of the earth.*—The ancients supposed the earth an immense plain, spread out in space; but modern science has determined its form to be a globe, or sphere, whose diameter is about eight thousand, and its circumference about twenty-five thousand miles. It is not a perfect sphere, being a little flattened at the poles. The variation from a perfect sphere is not sufficient to be taken into account for the purposes of these lectures.

352. *Irregularities of surface.*—The earth, in addition to the flattening at the poles, departs in shape from a perfect sphere, in slight irregularities of surface. On a perfect sphere all points of the surface are equally distant from the centre; but there is much unevenness of surface on the earth. The unevenness is of every possible variety, from the tops of the loftiest mountains to the depths of the lowest seas. The irregularity, however, would be scarcely perceptible to a being on another planet, inasmuch as the highest mountain on the globe bears no greater proportion to the whole mass of the earth, than would a grain of sand, one-twentieth of an inch in thickness, to a globe six feet in diameter; yet to us, who live on the surface, the inequalities appear very great.

353. *Origin of inequalities of surface.*—A particular form of material nature, either organic or inorganic, being observed to exist, it is the legitimate object of human

science to inquire, not only with what design that particular form was given, but by what means it was secured. The earth is uneven in shape. Now, the Creator might, in the beginning, without time and without means, make it so, or he might bring it to pass by the operation of natural causes. In the one case the event would be miraculous—in the other natural. In the creation, and the modifications of material existences, both miraculous and natural causes have been active. "In the beginning God created the heavens and the earth." This refers to the creation of *matter*, and was a miraculous event. Nothing but the *word* of the Almighty was necessary to create matter. No chemical laboratory was necessary, and no subordinate agents required to produce the result. When God had created matter, he gave it such laws to govern it as pleased him. No one law could be necessary more than another. Gravitation might exist, or it might not. If it existed, it might "decrease inversely as the square of the distance," or it might not. Matter might possess resistance, and be capable of being influenced and modified in its forms by heat, electricity, chemical affinity, and magnetism, or it might not. In giving matter the particular laws which it has, and in withholding from it others which it has not, God consulted his own will and good pleasure. He, however, had regard to wisdom and benevolence. The act of giving law to matter was miraculous. The modifications of matter, in accordance with the laws he has imposed, are not miraculous, but natural. When the operation of those laws is suspended or reversed, the act becomes miraculous. The level surface of water, or its slight elevations and depressions by wind, are the natural result of the law of gravitation; but the condition of the waters of the Red Sea, during the passage through it of the Israelites, was the result of miraculous interference with the law; for by no natural action could waters stand, for so long a time, in two walls

on the right hand and on the left. The creation of living beings of every species was a miraculous event. The giving them of the organic laws, whose operation is everywhere seen in living matter, was also miraculous. But the changes which they undergo, through the operation of these laws, are natural. The reproduction of living beings, in accordance with the usages of life, is natural; but the birth of Isaac was unnatural and miraculous.

To a philosophic mind the hand of God is as evident in a natural as in a miraculous event; but as there is a tendency in man to underrate or overlook the presence of the Divinity in natural operations, God is pleased, sometimes, to call our attention to some great truth by a miraculous event. It is not good philosophy to impute to miraculous interposition what may be as well explained by natural causes. Nothing is thereby added to the glory of God. His power, and wisdom, and goodness are as clearly seen in giving to nature laws, by whose usual operation desirable results are produced, as in the miraculous reversion or suspension of those laws. We may, therefore, assume that the form of the earth is the result of natural causes, and we may reverently inquire into those causes, and exhibit the wisdom and benevolence of the design.

If the earth were in a fluid state, it would naturally present no unevenness of surface; or, if inequalities should arise, they would remain but momentarily, as the waves of the ocean subside when the storm ceases. It is the law of fluids to maintain an equality of surface, unless agitated by wind or some other foreign agent. If, therefore, explosions and volcanic surges and agitations should occur, no permanent unevenness of surface could be produced, so long as the whole mass of earth were fluid. But should the surface, with a crust of greater or less thickness, become cooled down to the consistency of paste, so as, when moved or raised, to retain its position, the influence of volcanic

action below might elevate the surface in some places, and consequently leave a corresponding depression in others. Sudden, violent, and limited action might leave small and detached hills, with corresponding valleys. Slight action along a line might leave a swell or ridge on the surface. Powerful and long-continued action along a line might elevate a vast mountain chain.

We will illustrate our view by reference to the well-known shape of the surface forming the North American continent. Suppose the earth a semi-fluid mass, the surface having about the consistency of mush. The surface of the North American continent is supposed, in this condition, to be level. Let a powerful, gradual, and long-continued volcanic agency act along the line, from the Gulf of Mexico to the Gulf of St. Lawrence, and it would naturally elevate the land forming the mountain chain of the Alleghanies. The elevation of this chain would leave slopes on each side, extending on the east to the Atlantic, and on the west to the Mississippi. Let, either at the same or a different period, volcanic power act in the same way, from Mexico to the arctic circle, and it might elevate the Rocky Mountain chain, with the Pacific and Mississippi slopes. Should the action be in one place interrupted, and in another break out more powerful, detached mountains and spurs from the great chain would result. Thus, we have, at first, two great mountain chains, with several detached spurs and hills. The Alleghany chain would have, on the east, a slope, forming a regularly-inclined plain, extending to the Atlantic, and, on the west, another of the same character, extending to the depression where now flows the Mississippi. The Rocky Mountain range would, in like manner, have one regular slope to the valley of the Mississippi, and another to the Pacific. The slopes might be marked by intersecting ridges and valleys, just sufficient to determine the general course of the streams. Rivers might not then exist. Whether

any water could be found, at that time, on the face of the globe, would depend upon the extent to which the cooling process had been carried. In a high temperature water would exist only in vapor, filling the atmosphere, and spreading "darkness over the face of the deep." But, in process of time, the vapors would become condensed, and the waters would gather on the surface of the globe; and to the agency of running waters must we impute much of the uneven surface—the hill and the valley—of the earth. Whoever looks with a well-informed and careful eye over the Mississippi valley, can come to no other conclusion than that once the whole basin, from the base of the Alleghany to that of the Rocky Mountains, and from the Gulf of Mexico to the great lakes, was covered with water—that the bottom of this great sea was varied only by long lines of slight depression, near where the great rivers now run—that, either by the elevation of the whole of the lake, or the bursting or sinking of some barriers on the south, the waters were drained off; and that, in the draining, and in the long course of years since, the beds of the rivers were sunk to their present level, and the banks left in the shape of hills and mountain bluffs. Let any one stand on the banks of the Ohio, at the upper termination of the inclined plain, on the Madison and Indianapolis railroad, or on the top of the hill back of Lawrenceburg, and look over the whole country, so far as he can see, observing the course of the Ohio, the appearance of the banks, the effects of the tributary streams coming into the river, and the topography of the country in the interior, and he can but be convinced that the whole country was once nearly one general level, and that nearly all the inequalities of the great Mississippi valley have been, in the course of ages, produced by running water. Let him travel over any western state, and observe how, after proceeding for miles on a level plain, he descends gradually to the bed of a stream several hundred feet below

the general level of the country, and then ascends to the same general level on the other side, and he can no longer doubt the important agency of rivers in producing hills and valleys. It would, therefore, appear, that the general features of the earth's varied surface are owing to volcanic action; but that much of the minor detail of inequality has been produced by rivers and streams.

I do not say that God could not, by miraculous act, make, in the beginning, the surface of the earth just as it is, and make all the strata of the globe, and even the organic remains, just as we find them and where we find them; but I do not believe such was the origin of things. I believe that, since the first creation of matter "in the beginning," the world has been suffered to undergo its changes by natural laws, constantly, however, superintended by all-wise Providence. Those natural laws may have often been, and may often be again, suspended or reversed by miraculous power, for good and wise reasons.

354. *Advantages of uneven surface.*—About three-fifths of the surface of the globe is covered with water. Assuming the depressions in the ocean to be equal to the elevations of the land, it is plain that, if the earth were leveled off, "the mountains carried into the midst of the sea," and the hills smoothed into the valleys, the land would fill up the cavities in the waters, and the whole surface of the globe would become covered with water. In that condition nothing could live, but fishes and seaweeds. The existence of dry land, therefore, with all its vegetable and animal life, is owing to the uneven surface of the earth. Had, therefore, the Creator not found means of forming and preserving an uneven surface, his intention of forming the numerous species of vegetable and animal terrestrial beings must have been thwarted.

Consider, also, how much of beauty the earth derives from its diversified surface! A level plain, though teem-

ing with vegetation, soon becomes tiresome and tame. Few sections of earth are destitute of undulations. The western prairies are not level, but slightly diversified with valleys and ridges; yet these, with all their luxuriance and profusion of grass and of flowers, soon pall on the sight, and we pine for a hill and a vale. The fertile fields and magnificent woodlands of Ohio and Indiana, though marked by frequent undulations, and watered by numerous rivers and streams, present a landscape too nearly level to excite the higher emotions of the beautiful; but when you cross the Alleghenies, and stand upon the hills between the Hudson and the Connecticut, or on those between the Androscoggin and the Kennebec, you will see landscapes in which all the combinations of the beautiful cluster—hills of every form, variety, and shape—valleys, in which Calypso might delighted dwell, stretching away in verdure and loveliness, till they are lost in the mist and haze of distance—rivers rising among the distant mountains, and winding their meandering course, amidst picturesque scenery, to the ocean—and lakes whose surface is bright as polished silver, and whose waters are tranquil as thoughts of sleeping infancy. No natural scene on earth can be more beautiful than a New England landscape. In ornamented cottages, tasteful farm-houses, neat villages, shady streets, highly-cultivated gardens, and steepled churches, art has done much to render the landscape beautiful; but in diversified surface of hill and dale, distant mountain, flowing river, and silvery lake, nature has far surpassed the power of art. In some sections of the globe the beautiful mounts to the sublime. The craggy cliff, the overhanging rock, the inaccessible mountain summit, the long-extended range of lofty hills, excite intense emotions of the sublime.

355. *Influence of beautiful and sublime scenery.*—The influence of the sublime and the beautiful in nature cannot well be overrated. The brute seems incapable of any

emotion from natural scenery. The mountain, the valley, the hill, the plain, the lake, the brook, are all the same to it, if only they may supply it pasturage and drink. But man looks on nature with eyes such as brutes have not. The landscape may be painted on the eye of the ox, as well as of the man. But in the brute there seems no connection between the image on the eye and the soul. The animal, in fact, seems to have no soul. But man has a soul capable of being aroused to intense emotions, whenever a beautiful prospect bursts on his eye.

The influence of the beautiful in nature on the mind, and manners, and taste of man, is very great and very good. It refines, cultivates, and humanizes the soul. It gives character and permanence to the literature of a people, it promotes the influence of piety and devotion, and it strengthens nationality and patriotism.

Natives of a champaign country never become so strongly attached to their home as the mountaineer and dweller in the valley. Nor has Liberty ever long dwelt in a plain country. Her home is with the eagle on the mountain top, and along the hillsides, visiting the deep valleys, the ever-green glades, the flowery dells, but scorning the interminable, unvaried plain. Where is there a people who, with a champaign country, have acquired and maintained their freedom? The spirit of the people seems to partake of the tameness of the scenery. But if you wish to see exemplified the highest specimens of human virtue, go among the mountainous districts, and to portions of the earth diversified by hills, and valleys, and lakes, and rivers.

356. *Distribution of land and water.*—We have said (§353) that about three-fifths of the surface of the earth is covered with water. This might seem an unnecessary waste of space. Of what use, at least to man, can be so much water? Might not the ocean, which can support only whales and oysters, have been compressed into less space,

and left more room on the globe for dry land, on which can live birds, and beasts, and man?

We have seen (§298) the indispensable necessity of moisture to the support of vegetable and animal life. To furnish material for dew, rain, springs, and rivers, the ocean was formed of the right magnitude. There is now a certain amount of moisture appropriated to every place on earth. The amount varies in different places on account of various circumstances. But in the same place, one year with another, it seldom varies in any great degree. The mean average of rain falling during the year, at any one place, as London, Paris, Washington, Cincinnati, or St. Louis, is just about the same. One summer, or one spring, or one autumn, or one winter, may be dryer or wetter than the corresponding season of the preceding or the succeeding year. But the mean for the year does not perceptibly vary, and will not vary, so long as the ocean and the land maintain their present proportions. But let the ocean be diminished and the land increased, and the amount of water falling annually on any spot would be diminished. So let the ocean be increased and the land diminished, and the annual amount of rain in any place would be greater than it now is. The constitutions and the habits of the vegetables, animals, and man, of any particular place, are adapted to the usual average amount of moisture appropriated to that place. Let the amount be increased or diminished, and living beings would suffer. If the amount be materially varied on either hand, many species of plant would die.

Thus, we see the amount of water in the ocean wisely and benevolently proportioned to the amount of land on the globe, and the consequences thereof adapted to the constitution and wants of living beings.

357. *Geographical location and shape of the continents, islands, and seas.*—Take a map of the world and spread it

before you. Look at the western continent—the two Americas. Observe on the northern side of this western hemisphere the proportions of land to water in the torrid, in the temperate, and in the frigid zones, and then observe the proportions of the same in the zones south of the equator. Now look at the eastern hemisphere, containing Europe, Asia, and Africa. Observe the proportions of land to water in each zone, both north and south of the equator. You will perceive that in the western hemisphere the continent is very narrow in the torrid zone, not being over 10° in width, anywhere below the parallel of 30° , but increases in width as you go north. In the eastern hemisphere the continent is wide near the equator, being, along the parallels of 20° and of 30° , from the western coast of Africa to the eastern coast of China, nearly 140° in width, and it grows narrower as you go far to the north.

Now, the particular locality of land on the globe has much influence on the average temperature of the earth, and the particular shape and latitude of the continents of the western and eastern hemispheres, affect materially the climate of all places on those hemispheres.

The land, in warm latitudes, receives and radiates heat more easily than the water. Hence, in summer the land gets hotter, and in winter colder, than the neighboring ocean. Therefore, the existence in the torrid zone, and in the parts of the temperate near the torrid zone, of much land and little water, would produce a high temperature, which would be diffused more or less over the earth. A different distribution, much water and little land in the equatorial regions, would lower the temperature of the earth. But in higher latitudes the effect is different. The ocean, from its currents, has a tendency to preserve everywhere a mean temperature, which it communicates to the contiguous land, moderating alike the excessive heat or cold. The land in northern latitudes, especially if it be elevated

or mountainous, becomes a reservoir of cold, being covered with ice and snow. Snow, particularly, reflects all the heat falling on it from the sun, so that little or no elevation of temperature is produced by the sun's rays.

Any material change, therefore, of position in the continents and islands of the globe, supposing the size and shape to remain the same as now, would affect the average temperature of particular places, and of the earth generally. Should all the land be thrown into the torrid and temperate zones—and nearly every patch of land on the globe might be thrown into the space included between the parallels of 30° each side of the equator—the temperature of the whole earth would be so elevated, that probably all the present races of vegetable and animal beings would die. Should, on the other hand, all the land be disposed in the frigid zones—and without even altering the present shape of the continents, it might nearly all be placed beyond the parallels of 40° north and south—the cold would become so intense as to freeze up every thing, vegetable, animal, man, and perhaps the ocean itself. The species of vegetables and races of animals at present existing, are adapted, in their constitution and habits, to the mean temperature of the place of their locality. Man might adapt himself to a slight change. But many animals and plants could not do it. A great and sudden change to either extreme would kill off every thing living. The present distribution, therefore, of land and sea is precisely adapted to the present organized beings, and any change in the distribution would require a corresponding change in vegetable and animal life.

It should be observed, that mean temperatures only affect seriously animals and vegetables. A tender vegetable may be killed by a sudden frost, and a man may be frozen to death, or killed by a stroke of the sun; but, generally, animals and plants endure, without injury, almost any extreme

of heat and cold, provided the mean temperature be not altered. And that mean, for the year, seldom varies 2° in any one place. The annual mean of temperature is as uniform as the annual mean amount of moisture. While, therefore, one summer may vary from another, and one winter from another, the variations are equalized, so that the annual amount is the same.

It is remarkable that plants, indigenous to any place, will bear diminution better than elevation of mean temperature. Nursery-men will tell you that they find less difficulty in acclimating southern than northern trees. Trees from New England, transplanted to Indiana, do not suffer from the extreme heat of our summer weather, for there are days much hotter in Maine than in Indiana. But northern trees suffer from the increased annual mean of temperature, which they have to endure in our climate. Under this they become sickly and unprofitable.

These facts show, that any considerable increase of the mean temperature of the surface of the earth would not promote the health of plants and animals. We usually complain that the temperature of the earth is too low for our comfort and convenience. In this we are mistaken. It is neither too low nor too high, but just right.

Think you the continents and islands of the globe were thrown about at random? If so, how came such relations of adaptation, between the temperature depending on these random shots, and the constitutions of vegetables and animals, to exist?

358. *Motions of the earth.*—I know not as it was necessary that the earth should have any motion at all. Certainly there was no necessity why, in moving in its orbit, its axis should make an angle of precisely $23^{\circ} 27' 57''$ with the plane of its orbit. Other planets do not move in this particular position. The earth might just as well, for all any natural necessity, have moved with its axis perpendicular

or parallel to the plane of its orbit. But we shall see what special purposes are effected by this arrangement.

359. *The seasons.*—The earth moves around the sun once a year, in a curve called an ellipse. It differs but little from a circle. The circular path in which it moves is called its orbit. Suppose a thin membrane stretched over the circle, like a drum-head over the drum, and that would be called the plane of the orbit. Now, the earth might move with its axis perpendicular to this plane, in which case there would be no change at all of seasons; or with its axis parallel to this plane, in which case the change of seasons would be intolerably great; or it might move with its axis making any angle between 0 and 90°, in which case the seasons would vary from their present character, and the extremes would be greater, as the axis departed from a perpendicular position.

If the axis were perpendicular, there would be no change of season. Each part of the earth would receive the same amount of light and heat from the sun every day. It is true, there would be a slight variation, owing to the fact that the earth, in one extreme of its orbit, is a trifle nearer the sun than at the other; but the difference would be hardly appreciable. With the axis perpendicular, there would be little, if any, difference in temperature corresponding to latitude. The equator and the poles would share nearly alike.

Under such a state of season the great varieties of vegetable product now flourishing on earth, corresponding to latitude and climate, could not exist. The same species would grow in Louisiana and in Lapland. The products of Greenland and of Guinea would but slightly differ. There being fewer varieties of vegetables, fewer varieties of animals could be sustained. Man's comfort and means of support would be greatly diminished.

If the axis were parallel to the plane of the orbit, the

extremes of summer heat and winter cold would surely kill every living creature now existing on the globe. The present inclination of axis is adapted to the present constitution of vegetable and animal nature. The slightest change of inclination would require a remodeling of the entire terrestrial and marine organic world. The present constitution is further adapted to furnish a great variety of vegetable products. China produces tea, and Cuba coffee—France silks, and South Carolina cotton—Ceylon spices, and Virginia tobacco—Russia hemp, and Vermont wool—Canada wheat, and Louisiana sugar. The exchange of the products of different latitudes gives rise to commerce—the most important and lucrative branch of human industry, adding more than any other pursuit to the vigor and wealth of a nation, and to the sum of human knowledge.

The different productions of different climates afford both the stimulus and the means of commerce. We are prompted by our natural desires to possess the productions of foreign climates. Our own productions furnish us the means of purchasing theirs. The intercourse of nations with each other is thus secured. And none will hesitate to impute to such intercourse influences of the most happy character on the improvement and civilization of nations.

It is thus that God has been pleased, by so unexpected a means as the particular inclination of the axis of the earth to the plane of its orbit, to exhibit designs of good to man—designs of elevation of the human race in intellectual and moral improvement.

360. *Constancy of climate.*—The people of any particular place generally suppose their own climate subject to great extremes and sudden changes; and it seems, sometimes, that vegetable nature must die through inconstancy of the climate; but it is ascertained that, in respect of temperature as of moisture, (§356,) it is the mean only which affects plants. They will bear, as we have said, (§357,) any

extreme of heat and of cold, provided only the annual mean be not altered. In respect of the annual mean, climates are remarkably constant. We measure heat by the thermometer. We observe the degree three times each day, and take the mean of the observations for the temperature of the day. We then add the means of all the days together, and divide the sum by the number of days in the month, and thus obtain the mean of the month. From the means of the twelve months we derive the mean of the year. This mean seldom varies, in the same place, 2° for a series of years. We give a few illustrations. At Albany, N. Y., for the year 1848, the lowest temperature was -15° , and the highest 93° , making a range of 108° . The mean for the year was $49^{\circ} 50'$, and the mean for twenty-three years is $48^{\circ} 28'$. At Rochester, N. Y., the lowest temperature was 0° , and the highest 94° —the annual mean $48^{\circ} 33'$, and the mean for seventeen years $46^{\circ} 47'$. At Potsdam, near the St. Lawrence river, the lowest was -27° , the highest 92° , the annual mean $45^{\circ} 41'$, and the mean for twenty-one years $43^{\circ} 36'$. At Granville, Washington county, the coldest and the hottest place in New York, the lowest temperature was -30° , the highest 96° , the annual mean $46^{\circ} 30'$, and the mean for thirteen years $45^{\circ} 23'$.

The mean annual temperature of the city of London is $50^{\circ} 24'$. In 1796, when the greatest cold ever observed in London occurred, the mean temperature of the year was $50^{\circ} 6'$; and in 1808, when the greatest heat ever known in the city occurred, the mean of the year was $50^{\circ} 30'$.

These facts I have given, in order to show how constant the mean annual temperature of any place for a series of years remains. We may thus see how wisely climatic agencies are balanced and adjusted, so as to secure the plants of any place against injury.

361. *Relation between the length of the year and the*

constitution of plants.—There was no necessity why the earth should move just so fast in its orbit as to make the year precisely of its present length. The years of other planets vary greatly from that of the earth. The year of Venus is only two hundred and twenty-four days, while that of Jupiter is eleven times as long as that of the earth.

Between the length of a year and the constitution of vegetables on the earth there is a striking relation. As Professor Whewell, in his *Bridgewater Treatise*, remarks, "The vegetable clock-work is set and wound up, so as to go for a year." It then needs to be rewound up. The present constitution of plants is fitted only for the present length of year. Should that length be materially increased or diminished, "the working of the botanical world would be thrown into utter disorder, the functions of plants would be entirely deranged, and the whole vegetable kingdom involved in instant decay and rapid extinction." The functions of plants have, by their nature, a periodical character, and the length of the period thus belonging to vegetables is a result of their organization. Warmth, light, moisture, and soil may modify, hasten, or retard the stages of the period; but they cannot alter the length of the vegetable cycle, except within very narrow limits. In the existing state of things, the time of the earth's revolution round the sun and the time of the revolution of the vegetable functions of plants are equal. The two periods are adjusted to each other. The spring of the season, and the periodic time of the plant, the warmth of the sun, and the showers of heaven, all come at one and the right time; and to their relations of season, heat, and moisture, not only one, but a thousand species of plants is adapted. Surely all this could not be the result of chance. There is evident design in the arrangements and adjustments; and the evidence is clear that one and the same being designed the whole system of nature. There is a unity of plan, proving a unity of Divin-

ity. One mind must have directed all things, so that the humble violet of the wildwood should correspond, in its periodic changes, to the revolutions of the earth in its orbit.

362. *Diurnal motion of the earth.*—Why should the earth revolve at all on its axis? Why should, if it must revolve, its period of revolution be of the precise length of twenty-four hours? The final cause is evident. Without such revolution there would be no succession of day and night. One side of the earth would be always in the light—the other always in darkness. The one side would be unfitted for the residence of animals, by reason of heat and of no provision for rest; while the other would be uninhabitable for man, or beast, or vegetable, by reason of darkness and cold.

We also see a wise relation between the succession and length of day and night and the constitution of terrestrial animals, particularly man.

Man is so constituted as to need sleep. Without it all his faculties would soon be exhausted and his happiness extinguished. By a fundamental law of our nature, weariness and exhaustion invariably follow long-continued exercise, either corporeal or mental. By sound, healthy sleep both the body and mind acquire a renovated accumulation of those powers which are necessary for the purposes of active and intellectual life. Night is the season for sleep. With the departure of twilight cease all the usual stimuli of that sense which calls our faculties into action more frequently than all others. With the approach of darkness beast and bird, as well as man, are naturally inclined to compose themselves to sleep. Amidst the glare and bustle of day sleep could seldom be profound and healthy; but night—gentle, quiet night—was designed, in wisdom and in mercy, to furnish us the season of repose well adapted to our wants.

LECTURE XIV.

OTHER ADAPTATIONS OF THE LAWS OF NATURE.

Definition of law—Of the laws of electricity and magnetism—Origin and progress of electrical science—Nature of electricity—Diffusion of electricity—Animal electricity—Of gravitation—Law of gravitation—Design of gravitation—Relations between the earth and bodies on its surface—The relations of gravity to the motions, mass, and distance of the earth and other bodies of the solar system—Laws of friction—Laws of affinity.

363. *Definition of law.*—The primary and original meaning of the term *law*, a rule or mode of action prescribed and established by some authoritative power, seems retained in all the various modifications of the word. To distinguish the various senses or modifications of meaning with which we use the word, we merely prefix some limiting or defining adjective. When we speak of the mode in which material substances exist, and of the changes, motions, and relations which uniformly occur under particular circumstances, we call it physical law; when we speak of the mode of existence, growth, and decay of living beings, we call it organic law; when we refer to the rule prescribed by the Governor of the universe for the action of human beings, we call it moral law; when we speak of the rules prescribed by the supreme power of a state or city for the government of a people, we call it civil or municipal law. In all these senses, and indeed in every other in which the word can be properly used, there is implied some authoritative power establishing and prescribing a mode of existence, and a rule of action for the substance and beings subject to the law. Inorganic substances are endowed only with passive natures—what the philosophers call inertia. They can only act as they are acted on by other influences. It is true, we sometimes speak of material nature as exerting active agencies of various kinds. We speak of the action of the atmosphere,

and of heat, and of water, and of the power of gravitation; but no man ever supposed material nature had any power of voluntary action. Matter is endowed by the almighty Creator with certain properties, some necessary to its existence as matter, and some superadded for specific purposes. These properties give rise to certain changes in the form, position, and relations of material beings. But in no voluntary sense can matter be said to act. The most we can say of it is, that God has endowed it with the power and the susceptibility of effecting and suffering certain mechanical and chemical operations, which often have the appearance of intelligence and choice. The intelligence, however, is not in the matter, nor in the law, but in him who made the matter, and who gave it the law.

The case is much the same with vegetables. In addition to mechanical and chemical, they perform or undergo certain vital operations or changes, without intelligence and without choice, under the direction of an intelligent and wise Maker and Lawgiver.

Animals are subject to the same mechanical and chemical laws as matter, and the same vital laws as vegetables. God, however, has endowed them with the additional power of intelligence, of choice, of voluntary action. Their choice and voluntary acts are limited to such operations as come within the power of the voluntary muscles, (§89.) Man is endowed by the Creator with all the mechanical and chemical powers and susceptibilities of matter, all the vital power of vegetables, all the intelligence, choice, and voluntary power of the animal, and, in addition to all these, with a moral nature, a susceptibility of spiritual impressions, a power of virtue, by means of which he is made subject to moral law.

The only difference between physical law and moral law is this: physical law *must of necessity* be obeyed; moral law *ought of right* to be obeyed. The one cannot be violated

but by the being that made it; the other may be violated by the being for whom it was made. A treatise on physical law, or the law of nature, as it is often called, would describe how matter *does*, *will*, and *must* act, under given or supposed circumstances; a treatise on moral law would describe how men *ought* to act under given or supposed circumstances. We arrive at our knowledge of physical law by experiment and observation; we arrive at our knowledge of moral law from reason and revelation. In both we recognize the same almighty, eternal, wise, and good being, the creator of the heavens, of the earth, of man; the giver of all law, mechanical, chemical, mathematical, vital, and moral; the supporter of the material, the preserver of the vital, and the governor of the moral universe.

364. *Of the laws of electricity and magnetism.*—A treatise on the laws of electricity and magnetism would be only a description, founded on observation and experiment, of the mode and effect of the existence and action of these agents. I need not, for the purposes of these lectures, go through all the details of electric, galvanic, and magnetic action. They would prove dry and uninteresting. There are, however, a few general principles and facts to which I wish to call your attention.

365. *Origin and progress of electrical science.*—An old Grecian philosopher happened one day to rub a piece of amber, called in the Greek language *electron*, on his coat sleeve, and observed that it attracted light particles of lint and down. Supposing the power of attraction, which he discovered under these circumstances, to be limited to the amber, he called it electricity, or, as we might say, *ambericity*. Little or nothing more seems known of the subject till the beginning of the seventeenth century, when Dr. Gilbert, an English physician, observing that glass and several other bodies besides amber can by friction be made to attract light bodies, was led to the important discovery

that electricity exists in all material substances. During the latter part of the same century, Robert Boyle, one of those favored individuals whom God, in his wisdom and love to the human race, occasionally sends to earth on a special mission of science and of virtue, made many valuable contributions of facts discovered by his own experiments and observations. About the same time, Otto Guerrike, in Germany, invented a rude electric machine, from a globe of sulphur. In the early part of the eighteenth century, Grey, of England, and Dr. Fay, of Paris, made and published valuable discoveries in the science. In the middle of the century, Dr. Franklin discovered the identity of electricity with lightning, and greatly improved the electric machine. In the latter part of the same century, Galvani, in Italy, discovered the modification of electrical action known as galvanism. The discovery of galvanism led to a new science, electro-galvanism, or electro-chemistry, as it is usually called. Still more recently, there has been opened to us, in the subject of electro-magnetism, a new province of science, which establishes a natural connection, if not identity, between two powers before regarded as distinct.

So rapid has been of late the march of discovery, invention, and improvement in electricity, galvanism, and magnetism, which *may be* all one, that it is exceedingly difficult for one who has any thing else to do to keep pace with the science. The magnetic telegraph is only one of the results of the science. What other startling discoveries and inventions in the properties and applications of electricity are on the eve of birth we know not. There is, however, reason to believe that the influence of electricity on the phenomena of organic and inorganic nature is vastly more extensive and powerful than philosophy has ever yet discovered. Electricity is known to exist in some state in every material substance yet examined. It is, without doubt, of universal diffusion in nature. It is a source of irresistible mechanical

power, and *may be* the cause of all mechanical motions in the universe. It is known to influence chemical changes, and *may be* the cause of all chemical affinities and combinations. The limits of its connection with vital operations are not yet satisfactorily ascertained; but enough is known to induce us to believe it the most extensive and efficient of natural agencies in vital organization.

366. *Nature of electricity.*—It would not be expedient for me to enter into a prolix discussion of the experiments and theories on the nature of electricity. It is sufficient to say that probably electricity, as well as heat, is matter. Its state is supposed to be that of a subtil fluid. It is not a property of matter, but matter itself, so subtil as to be universally diffused amidst the pores of all other matter. Many of its properties resemble those of heat. Both may be generated. We do not mean they may be created. Probably all the electricity, all the heat, and all the light in the universe were created “in the beginning.” All that man may do is to bring them to accessible points and apply them to useful purposes. Both electricity and heat may be conducted through matter, and both pass much more readily through some substances than through others. Both tend to an equilibrium. Both are destitute of appreciable gravity.

But to show that electricity and heat are not one and the same substance, there are points in which they differ. Heat expands bodies; electricity does not. Heat passes off gradually from an accumulating body; electricity instantaneously. A heated body exhibits no attraction for a cold one; an electrified substance powerfully attracts one unelectrified.

Other resemblances and differences might be named; but these are sufficient for our purpose.

367. *Diffusion of electricity.*—There is, as we have seen, much similarity between the laws of electricity and of heat.

We have seen (§305) that if a heated body be surrounded by a cooler, the heat will be abstracted by conduction and radiation, until an equilibrium of temperature is obtained. The same tendency to equilibrium is known to attach to electricity. Heat may be accumulated by natural or artificial means, but it cannot be long retained in an accumulated state. Electricity may be excited and accumulated by a variety of means, but diffusion will sooner or later occur. If the electric be surrounded by conductors, the fluid, if, as is probable, it be a fluid, will be diffused as fast as excited, and no accumulation can occur. If surrounded by non-conductors, accumulation to a certain degree may go on; but, owing to the tendency to diffusion, a limit will be found. The tendency of electricity to equilibrium is the cause of lightning. One cloud becomes, by friction or otherwise, more highly electrified than another, and, from the tendency to equilibrium, the electricity passes from the more to the less excited cloud, and the passage is accompanied by the extrication of heat, and light, and by sound. If the earth have at any time more or less electricity than the clouds, the fluid will pass from one to the other in the same manner, and with the same effects, as from one cloud to another.

The law of diffusion by conduction being known, we are able to use for many purposes the electric machine, and to avoid the dangerous effects of lightning. The lightning rod is constructed on the principle of conduction, and steals away from the clouds gradually and harmlessly that electricity which, if suffered to accumulate, might explode over our dwellings with fatal effect. Lightning rods of sufficient number and extent, and proper construction, are effectual preservatives of buildings from all harm from lightning. The known non-conducting power of certain substances enables us to protect ourselves temporarily from flashes of electricity. If we are suddenly overtaken by a thunder-shower, no man, who has informed himself of the laws of electrical

currents, would stand in a thunder-shower under a tree, or over a mass of water. If he could not get on a heap of feathers, or some other non-conducting material, he would stand on as dry a spot of earth as he could find in the open field. Or, if he was in a dwelling, he would stand away from all known conducting matter.

368. *Animal electricity.*—We have seen (§192) that animals have the power of generating heat, and that they generally retain a temperature above that of the surrounding atmosphere. It is not certainly known whether animal bodies have the power of generating electricity. But there is reason, I think, to believe that such is the fact, and that many of the variations of health and disease in the animal system are owing to disturbances of the electric equilibrium. Not having access, in the place where I write, to any late writers on electricity, and having very few authorities of any kind on any subject to which I can refer, I must rely, in matters of doubt, on my own observation. I therefore suggest the theory—one which is confirmed by my own experience and observation—that our bodies are a source of electricity as well as of heat; that an adequate supply of the fluid is essential to health; that we give off to the atmosphere, and to surrounding bodies, the superfluous amount, in the same manner as we do of heat; and that changes in the electrical condition of the atmosphere and of surrounding matter generally, affect us equally with variations of temperature. If there be in the atmosphere a deficiency of electricity, it is abstracted too rapidly from our bodies, and we suffer as by cold. If there be excess, we absorb it, and suffer as by heat. I have no doubt but many of the diseases of man, especially epidemic diseases, are owing to sudden electrical changes. Little is known of this subject. It is worthy of patient, careful, and thorough investigation.

We have spoken of electricity, galvanism, and magnetism,

as only modifications in operation of one and the same agency. We cannot now go into argument or illustration on this question. The progress of science for the last few years has resulted in new and useful applications of electricity and magnetism, rather than in illustration of the nature of the wonderful agent, whatever it may be, so subtil and ethereal as to be known only by its effects. The subject furnishes a finer field for philosophic investigation, more fruitful in practical results than any other in the whole circle of the sciences.

The materials in this wide field of inquiry are pouring in on us so fast, and some of the facts are so astonishing, that speculation is in danger of going mad, and a thousand vagaries of fancy, and visionary theories, are swarming on the brain of countless pretenders. But sober philosophy and discreet science will yet set all right, bringing order out of chaos, and truth out of speculation.

We may then see evidences of design, of wisdom, and of goodness, where now all seems meaningless and barren of useful result.

369. *Of gravitation.*—Were there in the universe but one single particle or atom of matter, what philosophers call gravitation could not exist. But another particle or atom being in existence, the two exhibit a mutual tendency to approach each other. Should we attempt to prevent their approach, we should feel a pressure from each, similar to the pressure or dragging downward of a stone which we may be holding in hand. This tendency of matter to approach other matter is called attraction; and, as it is the cause of the weight of bodies, it is called gravity, or gravitation, from the Latin word *gravis*, which means heavy. It is by reason of gravitation that the planets move around the sun, and the moons around the planets. Were the planets not attracted by the sun, and by each other, they would move, if they moved at all, in straight lines, and

thus go off into unknown regions of space. By gravitation is produced the fall downward of all bodies within our reach. This solution of the problem of falling bodies was made by Newton, and is said to have been suggested to him by the simple fact of an apple falling from the tree to the ground. By gravity, also, bodies exert pressure when at rest on their supports.

Gravity is not considered a necessary property of matter. Newton considered it only an appendage. It is, probably, an additional endowment for wise purposes. It has generally been supposed to be universal. This, however, is not certain. Light, heat, and electricity have no appreciable gravity, and it may be doubted whether animal fluids within the living body are affected by gravitation.

370. *Laws of gravitation.*—The laws of gravitation are very few and simple. We will notice only two:

(1.) Attraction between masses of matter is mutual, and in proportion to the relative quantities of matter in each mass. On the supposition that the ultimate particles, or atoms of matter, are all equal, any two atoms would exert equal force of attraction on each other. But, if there be but masses composed of an unequal number of atoms, the force of attraction in the larger would be greater than in the smaller, and the difference of attraction would exactly correspond to the difference in the number of particles.

(2.) The second law is, that the attraction of two bodies, the one for the other, decreases, as the square of the distance between them increases. The law is generally stated as follows: *attraction varies inversely as the square of the distance.* Thus, if we suppose Venus one mile from the sun, the Earth two, and Jupiter three, the attraction of the Earth would be only one-fourth, and of Jupiter one-ninth, as much as of Venus.

371. *Design of gravitation.*—There would seem to be but two general purposes effected by gravitation. The first

is to establish certain relations between the earth and bodies on its surface, and the second to establish certain relations between the earth, and also other planets, and the sun.

372. *Relations between the earth and bodies on its surface.*—

Obviously the present order of nature requires, that bodies on the surface of the earth should be at the same time easily movable and yet in no danger of floating off into space. This condition is secured by the laws of gravitation. Attraction exists directly as the quantity of matter. Were it inversely as the quantity of matter, the smallest bodies on the surface of the earth would stick the closest to it; nor would it be possible to move a stone or an atom of soil. The body of a fly would be heavier than that of an elephant. Locomotion of man, or beast, or bird, or vehicle, would be out of the question. Every thing would be fixed as fate on the very spot where it might happen to be, and no earthly power would suffice to move it.

Attraction is inversely as the square of the distance. Were it directly—that is, if the farther off a body might be, the harder it pulled—the loose bodies on the surface of the earth would be attracted as much by the sun and the distant planets as by the earth itself. All weight would be annihilated. All things would float about, much as they sometimes seem to do when we are suffering the delirium of fever. If a ball were thrown with a slight velocity from the hand of a child, it would become a satellite of the earth, revolving around it for ever. Such a state of things could not exist without subverting the entire economy of terrestrial nature.

573. *Relations of gravity to the motions, mass, and distance of the earth, and of other bodies of the solar system.*—There are known to be about thirty bodies connected with our solar system. These all exert a mutual attraction on each other. They are all, too, in motion, with inconceivable velocity, and the security and stability of the system require

that the orbits they describe should be nearly circular. The problem then presented to the Creator of the universe was so to adjust the law of gravity that thirty bodies, moving at the same time, in given directions and with given velocities, around a common centre, and some of them around a secondary centre, all mutually attracting each other, should be found after many thousand revolutions in a place required. The mutual attractions of the planets must occasionally draw some of them from their prescribed orbits. But the law of gravity must be so adjusted as to cause these perturbations to balance and correct each other. And it has been so adjusted. By adopting the law of decrease as the square of the distance, the purpose is accomplished—the result secured.

When we take into account the number, masses, distances, and velocities of the bodies of the solar system, and consider that gravity had to be adjusted to them all, or, if the law of gravity was determined first, how these conditions had all to be adjusted to it, we are overwhelmed with the difficulty, and intricacy, and sublimity of the problem.

Nor is this all. Not only is our solar system, consisting, as we have seen, of some thirty bodies, each moving in its own orbit, with a velocity of more than sixty thousand miles an hour—a velocity two thousand times as great as that of the steam car over its iron track—retained, each body in its place, from age to age, by gravitation, but the principle or power of gravity extends farther still. There may be seen any clear night, by the naked eye, some thousands of stars. But take the telescope, and point it to any part of the heavens, and you see the thousands become millions. Arabian figures may hardly enumerate the infinite multitude of stars which shine in space. Philosophy teaches that each of these stars is a sun, shining by its own light, and probably surrounded by planets and their satellites, forming a solar system as extensive each as our own. Gravity extends to

all these. By observations on the double stars, Dr. Herschel proved that they revolve about each other in ellipses, in such a manner as to show that the force by which they are attracted to each other varies, as in our system, according to the inverse square. Later observations have detected a motion among the constellations and stars themselves. Each sun, our own among them, with all its attendants of its system, revolves with unknown velocities, and in unknown times, about some great centre of the universe.

Thus, gravitation not only retains the satellites in their orbits, as they revolve about their primaries, and the planets, as they revolve about the sun, but the solar systems themselves, as they revolve about the great centre. What a stupendous power, then, it must be! Omniscient must be the mind that invented it, omnipotent the hand that made it, and infinite the wisdom that superintends it.

374. *Laws of friction.*—Inertia, or passivity, is conceded to be a universal property of matter. By the law arising from this property matter at rest would never move, unless acted on by some force, and matter in motion would never stop, unless arrested by some force. But perpetual motion of terrestrial substances has never been attained. When a body cannot move without causing two surfaces to rub together, this rubbing has a tendency to diminish, and in the end altogether to stop the motion. This force, which arrests from motion bodies whose surfaces are rubbing, is called friction. It is an important property. Were it not for friction we could not walk, nor could we hardly stand. All substances on the earth, and on our tables or desks, if resting on a surface at all inclined, would be constantly slipping away. But in the mechanism of the heavens, where friction, if it existed, might greatly interfere with the motions of the planets, it is wholly wanting. It is remarkable, too, that no philosopher has succeeded in detecting the cause of friction. It is evidently not the result of any other properties

of matter. It is a separate and distinct property of itself, bestowed on matter to answer a specific purpose and design, present where that purpose requires, and absent where its influence might be detrimental to the motions of the solar systems.

375. *Laws of affinity.*—It is known to all, who have any acquaintance with the elementary treatises on chemistry, with what facility certain elements combine, and how absolutely others refuse all connection. The cause of attraction or affinity between any two substances, and of repulsion between others, is wholly unknown. Some philosophers impute it to electricity, but the matter is not yet clear. But whatever may be the cause, the design appears in a thousand beautiful illustrations. The elements, which in their pure state are acrid or poisonous, are kept naturally in a combined condition, in which their active properties are neutralized. Thus, the exceedingly-combustible element, hydrogen, is imprisoned in the incombustible compound, water. Chlorine, a corrosive and poisonous element, forms an essential part of the mild, innocuous, and healthy common salt. Oxygen, which, if concentrated and pure, would produce fatal effects, is restrained and rendered harmless by the neutralizing properties of nearly every thing it meets in nature.

On the other hand, the poisonous compounds do not exist naturally, but are usually formed by art. Nitric and Prussic acid are not evolved, so far as I remember, by any natural process, but are only obtained by art. Corrosive sublimate is the product of the laboratory, and calomel, both a poison and a medicine, of the apothecary shop.

It would seem, therefore, that generally all poisonous elements have affinities combining them naturally in harmless compounds, and all, or nearly all poisonous compounds are the products of art.

LECTURE XV.

OF THE BEING AND ATTRIBUTES OF GOD.

Summary of the evidence from nature that there is a God—Eternity of God—Omniscience of God—Power of God—Wisdom of God—Goodness of God—Unity of the Deity—Of the personal presence and agency of the Deity in nature.

376. *Summary of the evidence from nature that there is a God.*—We have shown that all bodies in nature subjected to chemical analysis may be reduced to primary elements, and we have reason to think that in the beginning all matter existed only in an elementary state. But this analysis throws no light on the original creation of matter. How came it to exist? From whence were the elements derived? The ancient philosophers thought matter existed from eternity. But this supposition, even if true, by no means answers the question. It only changes the time. Whether matter began to be six thousand years ago, or six hundred thousand, or from eternity, the question still recurs, how came it first into being? The only answer, on which a well-balanced mind can rely, is, there is a God, who created matter. We have seen matter assuming regular and beautiful forms—forms more perfect than any human hand can mold or shape with mallet and chisel. We have seen how invariable are the angles of crystals, and how uniformly any composition of matter, if left free to act, assumes the form of its species. We have inquired how this happens, and we have found that there is a law of nature called the law of crystalization, and in accordance with that law minerals assume their surprisingly-regular forms. But how came such a law to exist? Who designed the law, who established it, and who executes it? There is a God, who designed, established, and who yet superintends this law.

We have seen matter assuming the wonderful character

of vital organization, being formed into living bone, and nerve, and muscle; the bones connected by joints; the muscles endowed with contractile power; the nerves endowed with sensitive and motory power; a digestive apparatus, exquisitely organized, for the purpose of preparing nutriment for the body; a system of vessels to distribute the nutriment; a respiratory apparatus to purify the blood and to generate heat; and a complement of sensory organs to afford knowledge of outward objects—hands to feel, palate to taste, nostrils to smell, ears to hear, and eyes to see. We have inquired how matter has happened to assume these organized forms, and how the wonderful operations of the several departments of the organic machine are carried on. We have found that there is a general law of vitality, according to which, through the aid of chemical and mechanical laws, and other secondary instruments, the living body is generated, built up, and sustained. But we may still inquire, how came such a law to exist? Who designed it, drew up all its details, and stands ever near to see that all its requirements are fully and punctually met? There is a God, who designed the plan, superintended the structure, and preserves from decay the great temple of organic existence. He gave laws to life, as well as to matter, and by those laws life controls matter, and uses it for its purposes.

We have called attention to the curious laws of heat, of electricity, and of gravity—laws evidently exhibiting wise design—and we have inquired how those laws came to exist. And we are compelled to acknowledge that there must be a God, superior to all matter, to all law, to all nature.

Should we find, in our future investigations, that the laws of crystalization, of life, of heat, of electricity, and of gravitation, are not either of them primary laws, but that each may be traced back to some more general law; and should it further appear that all the laws, making up the full code of what is usually called the laws of nature, may be traced

to one and the same general law, not yet discovered, the inquiry would still be legitimate, how came that general law to exist? Suppose that the problem of the existence of the earth, with all its adjuncts and inhabitants, of the sun and planets of the solar system, and of all the stars of the firmament, be resolvable on what is called the nebular hypothesis; suppose that all the present forms of matter, the earth and all worlds, were once in a state of nebulosity, diffused like mist or thin wreaths of smoke through illimitable space, we may still ask, whence that nebulous matter? How came it to exist? Who designed the forms it should assume? Who ordained, established, and executed the laws, by which, in process of time, the nebulae became suns, and planets, and trees, and animals, and men?

No matter how far the question is carried back, how many secondary causes may intervene, nor how much the aid of nature or nature's laws may be invoked, the inquiry recurs at every stopping-place, who formed the plan, who drew out the design, who determined the process, who made the law, and who superintends the whole machinery?

The inevitable necessity of the conclusion, that there is a God, has not escaped the notice of those great minds, which have been occupied in the original discovery of the general laws of nature. Every great discoverer, without exception, has been peculiarly in the habit of considering the world as the work of God. Copernicus, Galileo, Kepler, and Newton, the four great discoverers of the system and laws of the universe, explicitly, distinctly, and repeatedly ascribe the plan, design, and execution to a supreme, intelligent, and benevolent Being, the first cause of all beings and things. Men who, like these, or like Pascal, Boyle, Black, and Dalton, have devoted their great powers to discover the general laws to which detached and disconnected facts may be referred, have never rested on those laws as a first cause, but have looked "through nature up to nature's God." But

men who have not been engaged in original discoveries, but who have been employed in analysis, in applying general laws already discovered to the explanation of particular facts, have always been prone to rely on the law, without looking for its origin, design, and author. Synthesis, the building up of a system of truth and philosophy, leads the mind through the minor forms of matter, through the beautiful organization of vital existence, through the cosmic order of the solar system, and the magnificent machinery of the heavens, to the great Author of the universe. Analysis, tracing out details and minute results, carries the mind down among infinitesimal quantities, where it can

“Inspect a mite—not comprehend the heaven.”

It is on this principle, perhaps, that we may explain the prevailing tendency, among cultivators of natural science in our times, to skepticism. No great discoverers have appeared in the scientific world for the last two or three generations. We are all engaged in analysis, in detail, in vanishing and infinitesimal quantities, in observing minute facts, in tracing and applying the consequences of general laws already discovered, and in turning our knowledge into money. The mind of modern scholars is a mere table of money-changing. Nothing is studied unless it promises good pay. Science is strained, and tortured, and excruciated, to get into some useful shape—useful merely as an agent for money-making. Under such a state of things, the tendency of the age to skepticism is only what might be reasonably expected.

377. *Eternity of God.*—However far back we may trace the origin of the material system, or even of the elements of matter, we are still led on to a time when the world was not, and the elements were not. But when we reach the first cause we instinctively rest in our inquiries. We cannot imagine any time when he was not. Any inquiry as to when he began to be, would appear, from the very reason

and nature of things, manifestly absurd. We are thus led by natural religion to the conclusion, that God is from eternity—a conclusion sustained by reason and by revelation.

378. *Omniscience of God.*—I want another word to express an idea, which I have in mind, of the attributes of the Deity, but the language of mortals affords no word to embody the thought. Perhaps omniscience will do, if we use it with two modifications of meaning:

(1.) When we consider the system of the universe, from the animalcule that floats in the clear cup of water you drink, to the full-grown and perfect man, and from the particle of dust that floats in the sunbeam, to the magnificent stars of the heavens, with all the laws, adjustments, and relations of the whole system, we are overwhelmed with the idea of the intensity and extent of the power of mind it required in the Deity to conceive and design the stupendous plan. The mechanism of the heavens, and the mechanism of a fly; the properties of revolving spheres, and of floating motes; the laws of crystalization, of light, heat, and electricity—of chemical attraction, of life, of motion, and of gravitation; the adjustments, relations, and harmonies of the whole system, and that, too, for untold ages, had all to be originally conceived and unfolded in the divine Mind. Conception of a great design, projection of some magnificent and original plan, can only be expected of the most powerful intellects. Inferior minds may execute what others have planned. Mere mechanical genius may even improve a great machine, which some master mind has invented. But to conceive, to plan, to design, are the highest attributes of superior intellect. The mind of the Deity—if we may devoutly use a human word to express the thought—must be intense, powerful, and comprehensive, beyond the utmost conceptions of human thought.

(2.) The usual meaning of the word omniscient, as applied to the Deity, regards the knowledge of things as they

are. It supposes no particular intensity of thought, or greatness of power—such as is often exhibited, though in a vastly-inferior degree, by human beings of exalted mind, and such as we have just endeavored to explain—but the simple knowledge of facts.

The former species of omniscience is taught us by natural religion—the latter by revelation. We might, from the evidences of incomprehensible intellect furnished by nature, infer that the same mind, which could form so magnificent a plan as that of nature, would know every thing that is, and was, and is to be, but the inference would not be a necessary one. But revelation comes to our aid, and teaches us that the past and the future, as well as the present, are all known, in all their minute details and most secret incidents, to the omniscient one, whose name is Jehovah.

379. *Power of God.*—It is difficult for the human mind to entertain any satisfactory conception of the intensity and sublimity of the Divine power. The best illustrations we can obtain are drawn from motion and physical force. Yet even these illustrations fail. We know how much effort it requires to lift fifty pounds from the earth; but we can form but little idea of the amount necessary to lift the Earth, and Jupiter, and Saturn, and the sun, and hold them suspended in space. We know how much power it requires to project from the hand a ball of a pound's weight; but we cannot comprehend the amount necessary to project the earth into space, with a velocity of sixty thousand miles an hour.

It is sufficient to say, that by natural religion we arrive at the conclusion, that there can be nothing, absolutely nothing, beyond the ability of the divine Being to perform. Omnipotence is a feeble word, but it is the best we have to express the thought.

380. *Wisdom of God.*—There is properly a distinction between knowledge and wisdom. We may, perhaps, express the difference between the terms by saying, that

knowledge implies merely science, or an acquaintance with facts, while wisdom implies skill in the application of facts, so as to produce by the best means a desirable end. It is in this latter sense that we impute wisdom to the divine Being. Throughout nature there are, as we have seen, innumerable instances of adaptation, of adjustments, of contrivances, of relations. Examples are noticed in nearly every section of the preceding lectures, and they will readily occur to the mind of the reader. All these indicate wisdom, unerring and infinite.

381. *Goodness of God.*—It has been a leading object in the preceding lectures to illustrate the Divine goodness; and I need here only refer to the subject. We may, I think, safely defy any one to produce, in the living system, or in the constitution of nature, an instance of contrivance plainly designed for purposes of evil. To inflict injury, to generate suffering, seems no part of the purpose of the Author of nature. Though the benevolence of the design may not always at first clearly appear, yet more careful and patient inquiry will always discover indications of good in every work of the Deity.

382. *Unity of the Deity.*—The careful observer of nature can never become a polytheist. Uniformity of design, consistency of purpose, and harmony of execution, mark all the works of nature. The existence of relations between distinct things, proves that one and the same mind designed, one and the same hand formed, the related things. Thus the relation of the lungs to air, of the eye to light, of the ear to vibrations, of the organs of motion to the element of being, all prove animals and the elements of nature to be the work of the same Creator. The action of the law of gravity on bodies on the surface of the earth, and on the telescopic stars, proves that one and the same being made the pebble which the child picks up on the sea-shore, and the most distant star of the universe.

Natural religion, therefore, teaches us that the Creator of the heavens and the earth, of the inorganic and organic world, of animals and man, is one and the same God.

383. *Of the personal presence and agency of the Deity in nature.*—It is difficult for us to conceive, and still more to express in human language, a clear idea of the mode in which God exerts his divine power in nature. But, after all, it is as easy to conceive how the divine Being can act on the universe, as how the human mind can act on the body. The soul of man is present everywhere in the body. It controls the movements and acts of the body. In the same manner the divine Mind is everywhere in the universe, ruling all things, “not,” as Newton says, “as the soul of the world, but as the Lord of all.” As the mind is the master of the body, directing its motions at will, so God is the Lord of the universe.

There are two modes in which physical events might be brought about by Divine agency. The one consists in insulated interpositions of power, exerted in every particular case; the other in the establishing of general laws. But the act is in both modes equally of Divine origin. Law can have no active power. It only expresses the mode in which God works. When we speak of the laws which God has given nature, we do not mean that such laws have any power to execute themselves, or that any department of nature has power to execute them. The laws of nature suppose an agent, a power, conscious of the relations on which the laws depend, producing the effects which the laws prescribe. The laws of nature may be considered, not the laws by which nature acts of itself, but the laws which God, in his wisdom, prescribes to his own acts in nature. We may adopt the language of Dr. Samuel Clarke, the disciple and friend of Newton: “All things, which we commonly say are the effects of the natural powers of matter and laws of motion, are, indeed, the effects of God’s

acting upon matter continually, and at every moment, either immediately by himself, or mediately by some created, intelligent being. Consequently, there is no such thing as the course of nature, or the power of nature, independent of the effects produced by the will of God."

A common and natural event is as much, therefore, the act of God as a miracle. The only difference is, one event is brought about in an ordinary and the other in an extraordinary manner. But one and the same agent performed the act in both cases.

This was evidently the opinion of Bacon. He says, "I believe that, notwithstanding God hath rested and ceased from creating since the first Sabbath, yet, nevertheless, doth he accomplish and fulfill his divine will in all things great and small, singular and general, as fully and exactly by providence as he could by miracle and new creation, though his working be not immediate and direct, but by compass; not violating nature, which is his own law on the subject." This was, also, the opinion of Newton, and of the distinguished thinkers of the seventeenth century, who adopted the Newtonian philosophy.

This view of the physical agency of the Deity, may throw some light on the Divine omnipresence. By the mode prescribed in nature's law, God is operating at all times, and in all places. We may adopt the language of Newton: "God is omnipresent, not by means of his virtue alone, but also by his substance, for virtue cannot exist without substance. In him all things are contained and move."

We are thus led by natural religion to the same doctrine of divine omnipresence, so beautifully expressed by the Psalmist: "Whither shall I go from thy Spirit, or whither shall I flee from thy presence? If I take the wings of the morning, and dwell in the uttermost part of the sea, even there shall thy hand lead me, and thy right hand hold me."

LECTURE XVI.

OF THE ATTRIBUTES AND RELATIONS OF MAN.

Complicated nature and relations of man—His relations to matter—To animals—To spiritual existences—Power of reflection—Susceptibility of improvement—Conscience—Adaptation of man to his place in the universe.

384. *Complicated nature and relations of man.*—In the universe of God, man, more than any other being, seems the connecting link between the lowest and the highest orders of beings. He combines in his nature the properties of matter and of mind—of the mortal and the immortal—of the sensuous and the spiritual. To appreciate his relations we must contemplate him as a physical and a moral, an intellectual and a sentient, a material and a spiritual being.

385. *Man's relations to matter.*—Through his material body man is related to matter. He has all the properties and is subject to all the laws of matter. He has solidity, extension, form, and divisibility. He is subject to heat, electricity, and gravitation. He impresses other matter, and is impressed by it, by the same laws and in the same manner any one mass of ordinary matter affects another.

386. *His relations to animals.*—Man is related to animals in several ways:

(1.) He has the same physical organization as they. The bones, muscles, and nerves are made of the same material, and have the same appearance, and answer the same purposes, as theirs. The form and shape of his body and the organs of motion, are equally with theirs adapted to his element and mode of life. His stomach, blood-vessels, and lacteals resemble theirs, in all essential respects. No difference can be detected in the blood. Both animals and men have organs of respiration, though differing in form, of the same general structure and design. Both have the

same number of senses, similarly organized, and designed for the same purpose. Both commence their being, develop their form, advance to maturity, decay, and die, by the same general laws.

(2) Man is related to animals by the possession, though in different degree, of the same instincts, appetites, propensities, affections, and intellectual faculties. There can be no question that men, equally with animals, are governed, in a great variety of circumstances, by pure instinct.

The appetites of men and beasts for food and drink seem of the same nature, and originally equally strong and discriminating. Habit and luxury modify the appetites of man, and so they might of beast. Of the propensities, curiosity, imitativeness, emulation, and sociality are surely as evident in the conduct and habits of some animals as of man.

Animals have affections as well as men. They are influenced by anger, fear, love, and sympathy.

It is difficult to determine the limits of resemblance and of distinction between the intellectual faculties of animals and of men. That animals are influenced by associations of time, place, and resemblance, that they remember, and that they reason to a certain extent, there can be no doubt. That their thoughts are ever associated by the law of cause and effect, that they are susceptible of emotions of the sublime and beautiful, and that they reason mathematically, there is doubt. Their power of reasoning seems limited to very simple processes; nor is it possible, by education, so to develop their intellect as to embrace within its scope any thing beyond the sensuous and material.

387. *Relations of man to spiritual existences.*—In addition to the material and the animal, man has a spiritual nature. By virtue of his material nature, he has appropriate attributes allying him to the material world. By virtue of his animal nature, he has instincts, appetites, propensities, and

faculties, allying him to the animal world. By virtue of his spiritual nature, he has attributes, powers, and faculties, allying him to the spiritual world.

We will call your attention to some of the attributes of man, distinguishing him from animals, elevating him in the scale of being far above all beings of a mere material and animal nature, and connecting him with spirits, and with angels, and with God.

388. *Power of reflection.*—Man is endowed with a mental power, which Mr. Locke calls reflection. The word is not precisely what I want, but I can find no better. The ideas of brutes begin and end in sensation. The ideas of man, in his corporeal state, begin also in sensation, but end not there. The mind of the brute can entertain only such thoughts as are suggested by outward and material things. He can gather no new idea from thinking and reflection, nor can he carry on any long process of reasoning. The soul of man can entertain thoughts which never entered by the senses, which have no connection with the senses, and which have no relations to sensuous objects. By an internal sense he takes cognizance of spiritual objects—he holds communion with spiritual beings. By observation of nature's work, he is led to a conception and acknowledgment of nature's God. To this the brute can never attain. Nor could the highest order of animal ever, by observing the motions of the heavenly bodies, if he ever could even get an idea of motion, discover the properties of the ellipse in which all the planets move.

How far the connection of the human mind with matter, through the body, may be necessary to the beginnings of thought, we do not certainly know. The doctrine of Locke, that sensation is originally necessary to wake the mind from a dormant state, is received by most, and, perhaps, all metaphysicians. But it is by no means certain, that the human mind could not be capable of entering on a career of

thought, without ever being affected by sensation. However this may be, certain it is, that when once the fountain of the soul is unsealed by sensation, it flows on for ever. When once the soul has risen up by the aid of external supports, it may throw aside its crutches, stand in its own strength, and walk forth in its majesty through the illimitable fields of thought and truth. Man is thus allied to God in his intellect, as in his immortality. He receives the beginning of existence on earth. He is dependent for it on physical causes. But once begun, he never ceases to be. So there is to him a beginning of knowledge. It may depend on sensuous and material agencies. But the spring once touched, and the intellectual machinery set in motion, it runs on, independent, perpetual.

389. *Man susceptible of improvement.*—There are limits of intellectual development, which brutes may never pass. At that limit they soon arrive; nor may any education suffice to advance them further. And whatever eminence any individual may attain, there is no transmission of improvement to the next generation. The shepherd dog of Scotland is no more advanced in intelligence, than he that watched while his master slept on the plains of Chaldea. The sparrow builds now, on the rustic beam of my study, the same kind of nest her ancestor placed on the deserted altar of the temple.

But who shall set limits to the improvement of the human mind? There are, it is true, boundaries of knowledge, but no boundaries of mind. There are subjects, which, for some reason, we cannot comprehend; but there are no attainable limits of mental development. Nor are the attainments of one generation unavailable in the next. Improvements of one age may be handed down from age to age, accumulating as they descend. I need not enlarge on this point. The capacity of man for immeasurable increase in knowledge, and for unbounded development of

mind, obviously forms the distinctive trait of his nature, connecting him with supreme Intelligence.

390. *Man has a conscience.*—The characteristic property of man—that by which he is distinguished from all other animal natures—that without which he would not be man—is a moral sense—a conscience. Whether conscience be a distinct faculty of the human mind—a faculty original and uncompounded—or whether it may be resolved into ulterior or ultimate principles of the mental constitution—be it an element, or a combination of several elements, it is never wanting in human beings. To it man owes his capacity for virtue. The brute knows nothing of virtue; nor could he ever entertain the slightest conception of its nature. Without conscience, man would be totally incapable of virtue or vice. With it, he may vie with angels in virtue, and approach in perfection the holy One. As conscience forms the distinguishing characteristic of man—as it forms the whole foundation of a virtuous life—as it connects, more than every other principle, humanity with the Divinity—we may be allowed to call your attention to a few additional remarks on the subject. Over all the appetites, passions, and propensities of man's nature, and over all the acts of his life, Conscience sits supreme arbiter and ruler. He feels that her decisions are supreme. From them he never thinks of appealing. Its peculiar office is to tell man what he ought to do. It tells him, and it makes him feel, that the obligations of morality, that justice, truth, and humanity are binding on him. It is not, however, maintained that Conscience always has actually the direction of human conduct, but that man feels she ought to have. Every man does not obey her dictates, but he feels he ought to do it. Though Conscience may not always be the reigning, yet every man feels she is the rightful sovereign of his soul. She may be fallen from her dominion, and have lost the power of enforcing her commands, yet still she has the

right to rule, and man feels it so, and cannot help it. She claims the mastery, or regulation, over the whole man; the arbitration and direction among all his propensities. To preside and govern belongs to her from the very constitution of man.

When man acts in accordance with the dictates of conscience, he acts virtuously. And we may add, no act is worthy of being called virtuous, unless it be done because we feel that we ought to do it. There is no virtue in an act which you do involuntarily, or to please a friend, or to secure some selfish interest, or through the influence of any natural appetite or propensity. But when you do an act conscientiously, because it is your duty to do it, because you feel that you ought to do it, then it becomes virtuous.

By means of conscience, therefore, man is capable of forming a religious character, of perfection in virtue, of becoming like the angels and like God.

Relation of revelation to conscience.—We may be asked, if such, so high, so authoritative, so important, be the office of conscience, what necessity could exist for any revelation to man of his duty? Was not conscience of itself sufficient to teach him duty?

We have not said, nor do we intend to say, that it is the office, or in the power of conscience to teach us truth. When truth is discovered by the intellect, conscience requires us to receive it. Conscience cannot unfold to us the relations between us and other beings. But when these relations are made known by reason or revelation, and the duties growing out of them are perceived, conscience requires us to fulfill the obligations imposed by our relations. A revelation, therefore, was necessary to teach us truth and duty, that conscience might have means of enforcing the moral obligations of our nature.

Relation of the remedial system of Christianity to con-

science.—While without conscience man would be totally incapable of profiting by any Divine revelation, utterly devoid of any affinity with virtuous beings, and destitute of susceptibility of the remedial influences of Christianity, yet without those remedial influences, conscience, in the actual condition in which man is by nature found, would be totally insufficient to virtue, happiness, and heaven.

In the fallen condition of man, Conscience is dethroned. Her prerogatives are outraged by the lawless appetites of our nature. The inferior principles of our constitution are in uproar and wild mutiny. Among our principles, conscience, to use the illustration of Chalmers, was designed to act the part of the regulator of a watch among the other machinery. The watch has by a fall or some other accident received injury. The regulator is broken or unhinged. The wheels, therefore, are running at random. The regulator has lost its power, though not its right, to control the movements of the watch. It was designed to control, it has the right to control, it ought to control, but under present circumstances it cannot. The watch must be overhauled and repaired. The regulator must be restored, the other machinery subdued to obedience, and the whole order of proceeding changed.

Man's moral nature is badly out of fix. He needs purification and renewal. The influences of divine grace are necessary to restore his conscience to its rightful position. Without such restoration man must lie in ruins, a being of no account in the moral universe of God. The Christian system provides a remedy. It reveals to us a Restorer, the same who in the beginning created man, coming again, at the promised time, to restore him to the position he was originally intended to occupy.

391. *Adaptation of man to his place in the universe.*—Man is thus adapted to his station in the universe of God. His

adaptation to his place among material and animal natures consists in the possession of intellectual and physical powers far exceeding any other creature.

By his intellectual powers he may understand the laws of combination, decomposition, and reconstruction; the mechanical laws of wind, water, steam, light, heat, electricity, and magnetism; and the habits, properties, faculties, and uses of animals.

By his physical structure, his bodily organs, particularly the hand, he can apply his knowledge of matter and of mind to useful purposes. We are hardly aware how important to man is the peculiar structure of that small organ—the hand; how numerous are the relations between the hand and the intellect. Dr. Kidd, in his *Bridgewater Treatise*, says, “It is the human hand which gives the power of execution to the human mind; and it is the relative position of one of the fingers to the other four, which principally stamps the character of the hand; for the thumb, by its capability of being brought into opposition with each of the fingers, enables the hand to adapt itself to every shape, and gives it that complete dominion which it possesses over the various forms of matter. Give all the intelligence you please to the horse, or to the elephant, yet with hoofs instead of hands it is impossible it could construct the simplest instrument. Nor could the organs even of the beaver, were that animal gifted with the highest intellectual powers, enable it to effect much more than it is capable of effecting at present.”

Sir Charles Bell has written an entire treatise on the mechanism and vital endowments of the hand, as evincing design, and concurs, in his conclusion, with Galen, that the hand, by which man may execute whatever his ingenuity suggests, was given him because he was the wisest creature.

Man's adaptation to his place among spiritual nature

consists in the attributes of intellect and conscience. By the faculties and powers of his intellect he may discover truth, his relations to animals, to his family, to his country, to his species, and to his God. By proper exercise of his intellect he may discover the obligations and duties growing out of those relations. By conscience he feels the force of moral obligation, and is rendered capable of virtue, of holiness, of happiness, and of heaven.

LECTURE XVII.

GEOLOGY AND REVELATION.

Divine revelation—The Bible—Historical truths of the Bible—Moral truths—Doctrines—The creation—Geology—Period of the primitive formations—Period of the transition formations—Period of the secondary formations—The coal series—How fossils are preserved—Deposit of sandstone—Secondary limestone—Remarkable organic remains—Chalk series—Period of the tertiary formation—Age of the pachydermata—Age of the mastodon—Gradual preparation of the earth for man—Progressive development of organic life—Design of change and revolution—Time—Consistency of geology with revelation—Creation of the earth in the beginning—Formless and uninhabited condition of the earth—The six days of creation—Age of the world.

392. *Divine revelation.*—We have seen, in the course of these lectures, innumerable proofs of the existence, and illustrations of the attributes of God. We have also briefly noticed the place of man in the universe, and his attributes qualifying him for the position he holds.

The ability of God to make, and of man to receive any communication or Divine revelation, cannot be doubted by any reasonable mind. God could make known to man truth, by his works of creation and providence; by audible communications in human language; and by insensuous and spiritual inspiration. We believe that God is yet teaching man, by his works of providence; that he did in olden times address human beings in human language; and that he did inspire "holy men of old" by the Holy Spirit to speak and to write truth. That he does not now speak to you and to me in human language, or inspire us to speak and to write truth, is no more argument against the fact that he once did thus to others, than is the suspending or cessation of creating power an evidence that it never was exercised.

393. *The Bible.*—We have a book which we verily believe embodies all the revelation God ever made to man.

Whatever special and private communications God may have been pleased to make to favored individuals, for specific purposes, no other or additional revelation of interest to the human race seems well-authenticated. The truths of the Bible are mostly historical and moral. What may be properly called physical, or philosophical, or scientific truth forms no part of the design of Divine revelation. God was pleased to leave man to find out for himself, by the due exercise of his own intellect, the truths of philosophy and natural science. Whenever matters of this kind are mentioned in the Bible, it is by way, not of revelation, but of illustration. The inspired writers often allude to the known facts and phenomena of nature, and to the apparent condition and laws of the material universe. But they seem to do it only for poetical ornament and illustration. They never pretend to speak of natural laws by way of authority, as revealing any thing unknown to man before. Historical truths, involving facts of importance in the moral and spiritual economy of man, religious doctrines, and moral precepts form the great body of the holy Scriptures.

394. *Historical truths of the Bible.*—The principal points of historical truth to be noticed are the creation; the common parentage of the human race; the deluge; the history of a branch of the family of Abraham for several centuries; and the advent, life, death, and resurrection of Jesus Christ.

395. *Moral truths of revelation.*—The moral truths of revelation embrace, in a succinct and constitutional form, the rights and duties of man. These truths are embodied in great and general principles, and often in positive and special enactments.

396. *Doctrines of the Bible.*—There is another class of truths taught in the Bible. I can hardly call them historical, or moral, or scientific. I do not know by what name writers on theology usually call them. They are a species of fact. I refer to revelations of the nature and attributes

of God, either confirming the deductions of natural religion or revealing new attributes, on which nature throws little or no light. I include also revelations of facts regarding the nature and destiny of man, his primitive state, his fallen and depraved condition, his hope of renewal and restoration through the atonement, the future prospects of the race on earth as foretold by prophecy, and the resurrection of the body. I still further include the revelations of a future state of existence, and of the habits and employments of the dwellers in the spirit land.

For the want of a better term, I will call these facts doctrines.

I propose in a few lectures to call your attention to such evidences in favor of these several classes of truths as have the most influence on my own mind. For forty years have my thoughts been more or less intently devoted to searching out the reasons of my hope and faith in divine revelation. Much has been written on the various kinds of evidence bearing on the subject. I have read some, and thought more, without attempting to follow or designing to avoid the course any writer may have pursued. I shall present the subject in the natural order in which it appears to my own mind, and shall rely on those kinds, and particular specifications of evidence, which have the highest authority with myself.

We will first notice some evidences of the historical truths of the Bible.

397. *The creation*.—It must be well known to you that the Mosaic account of the creation has been supposed by many inconsistent, and perhaps irreconcilable, with the science of geology. The difficulty has been greatly increased by the ill-judged efforts of certain bigoted theologians to cut, instead of untying, the knot. Men who, perhaps, never saw the outcropping of rocky strata, never examined a fossil in its native bed, and hardly know one mineral substance

from another, sitting down in their study, their view limited by four brick walls, a plastered ceiling, and a carpeted floor, have gravely undertaken, and rashly presumed, either to deny outright the well-authenticated facts of geology, or, admitting them, deny the legitimate and necessary conclusions therefrom, and frame from their own brains and fancy theories of the earth to conform, not to the Mosaic history, but to their crude notions, and mistaken interpretations of that history. This is all wrong. The same God who made the earth and nature, gave us the Bible. The teachings, therefore, of the two books—the book of nature and the book of revelation—must harmonize. Coincidences between the doctrines of the two books may not often be expected, because they treat generally of different subjects. But where they approach the same line of facts, they must coincide. Should we ever find the well-authenticated facts of science, or the necessary conclusions drawn from them, or the demonstrations of mathematics, to conflict with our interpretation of some passage of the Bible, we ought to review our interpretation. By doing this we may find unexpected coincidences between science and revelation, and derive therefrom new and unanswerable arguments for the inspiration of the holy Scriptures.

398. *Geology*.—As the relation of geology to revelation is a subject of much discussion, and of great interest; as you must often meet in your reading, and perhaps in your observation, with facts difficult for you to reconcile with the common interpretation of the book of Genesis; and as I feel, and long have felt, from my high veneration for the Bible, and from my theoretical and practical acquaintance with geology, very much interest in the bearing of the science on revelation, I may be allowed to call your special attention to the question. I will first give you an epitome of the facts and theories forming the science of geology. “Geology,” to use the eloquent language of Wiseman,

"may truly be called the science of nature's antiquities. Fresh and young as Nature may look to us, and ever vigorous in all her operations; free from all symptoms of decay as her beauty and energy may appear; yet has she, too, her olden times, her early days of rude contention and arduous striving, and then her epochs of gentler rule. And the legends of all these she has written on monuments innumerable, scattered over the boundless tract of her supreme dominion, in characters which the skill of man has learned to decipher. She has her pyramids in those mountain coves which rise in every continent; her mighty aqueducts in the majestic rivers, which bestride large territories; her landmarks and local monuments to note the times and places of her victories over art, or of her defeats by a stronger energy than her own; and her cemeteries, where the bones of early generations lie inurned, yea, embalmed, by her preserving hand, with evidences and proofs of when they lived, and how they died."

Period of the primitive formations.—The ante-human history of the earth, as read by the geologist, may be divided into several periods. Passing over, at present, the original creation of matter, which God made in the beginning, let us look at the history of the primitive formations.

Beneath the soil, the diluvial debris, the coal, the sandstone, the limestone, and slaty formations, is found a series of rock, which the geologists call the primitive. The series consists of two classes—the unstratified and the stratified. The unstratified is usually known as granite—the stratified are principally gneiss and mica slate. There is no proof, and, from the circumstances of the case, there can be none, yet, from reading and observation, I fully believe that the primitive class of rocks, particularly the unstratified, in other words the granite formation, extends entirely around the globe, encircling the inner and perhaps yet liquid parts of the earth, like the inner skin of a cocoa-nut, forming everywhere

the lower surface of the crust of the earth. In places, however, it is broken, leaving openings between the atmosphere and the interior of the earth. Through these openings burning lava is often poured, by volcanoes, on the upper surface of the earth. Should we dig down anywhere deep enough to get through the tertiary, secondary, and transition formations, I have no doubt but the granite would be found everywhere, underlying all the other series of rock.

In some parts of the earth the granite lies on the surface, or only covered by a thin bed of soil. These are called primitive countries. The most of New England is a primitive region. Except in a few places, the work of change in the eastern Atlantic states ceased with the primitive period. No other series was deposited above the primitive. In the Mississippi valley there is a series of secondary formation of immense depth. Here, if the granite be found at all, it must be dug for deeper than we may desire to go. In many secondary regions, however, granite is found at the surface, being thrown up by volcanic action. It forms the highest mountains on the globe. If you examine a granite mountain in a secondary country, you will find the secondary strata at its base broken, and the granite protruded and thrown from below into lofty peaks. I have seen it spread out and plastered over rocks of the upper strata, evidently having been thrown up by volcanic action in a state of consistency much resembling that of paste, and, after reaching the surface, cooling and hardening, so as to become of the same character as that in the native quarry.

It is perfectly clear to the observer, that granite, however hard and solid now, was once in a soft and probably fluid state. I cannot well exhibit to you the evidence, from the small specimens on the table before me, and still less can I do it to the reader. But if you will go with me to some of the granite quarries of Maine, or climb with me some of the mountains of New England, I will show you proofs,

whose force you must feel to demonstration. You will observe disseminated through the granite very delicate and perfectly-regular crystals, sometimes of the materials of which the rock is composed, and sometimes of various other minerals. We can conceive of no way whatever in which these crystals could be so formed, and disposed, unless the matter of the rock, and also of the crystal, were fluid. Being fluid, and suffered to act freely, the particles of mineral, by the laws of affinity and crystalization, would naturally assume the very shape in which we find them. Few would adopt the theory of the rustic, who came along one day, as I was drilling a beautiful crystal of beryl from a granite ledge, and gravely and warmly contended that the Indians came along and stuck the crystalline minerals in, while the rocks were soft. He could not satisfactorily explain how the rocks came to be soft, nor how the Indians manufactured the minerals.

There is no difficulty in believing that the heat of the earth might once be so high as to hold the entire substance and mass of the globe in a melted state. There is strong evidence that even now the interior of the globe, below the granite crust, is in a heated, perhaps melted condition. The evidence of this state of the earth we will briefly notice.)

(1.) There is known to be a gradual increase of heat, as you descend beneath the surface of the earth, after you pass the point where the sun's rays have any influence. The increase is one degree for every sixty feet. At this rate of increase, at less than three miles below the surface, water would boil, and at the distance of a few hundred miles, the most solid rocks and hardest minerals would melt.

(2.) There are in many parts of the world warm springs, some of which send up boiling water. The heat to keep up their temperature must come from the interior of the earth.

(3.) There exist now, in various parts of the world,

numerous volcanoes which throw up melted rock. Volcanoes were much more numerous in ancient than in modern times. I have seen it stated that there are, I think, more than sixty extinct volcanoes in the neighborhood of Vesuvius. Nearly all the southern and central parts of France are said to be volcanic. Most of the region between the Rocky Mountains and the Pacific Ocean exhibits, it is said, indubitable indications of intense volcanic action, at no very distant period. There is, therefore, reason to believe, that there yet is, far below the surface or crust of the earth, a globular sea of melted matter, glowing with heat, its waves dashing over the sides of the volcanic crater.

Before the formation of the primitive rocks, this melted matter formed the surface of the globe. There was then no crust. All was a sea of burning lava, of melted metals, and liquid rocks. No island appeared in this fiery sea, nor living thing dwelt in its burning waters. In process of time the surface of the mass cooled off, crystalizing as it cooled. After it had assumed a half-solid, yet semi-liquid consistency, the crystal being well formed, the mass cracked into columnar shapes. You never find the crystalline primitive rocks in continuous sheets of any great length. The ledge is broken by seams or joints. You can seldom find a column more than one hundred feet in length, by as many in breadth. Generally the columns are only a few feet in dimension. You will discover this structure in every ledge of granite, especially if you attempt to quarry it.

It is found, by experiment and observation, that columnar structure is the law of form for all fluid masses cooling gradually. Ice cracks into blocks. Clay mixed with water and drying in the sun assumes columnar forms. You will find the law prevail over any substance on which you please to try the experiment.

When the granite had cooled, and formed a crust, the earth was not a perfectly-smooth ball. The crust did not

encircle the globe even, like the coat of an onion. There were irregularities and inequalities, occasioned by local differences of cooling, and by the action of internal heat. This uneven surface being exposed to the atmosphere, and to the action of matter, would immediately begin to decompose. The matter, worn off from the rugged surface by the elements, would be carried by water down into the valleys. Being there slowly and tranquilly deposited, it formed the stratified primary series. This series is composed of precisely the same elementary and constituent materials as granite. But, instead of being crystalline, it is merely stratified, or slaty. The deposits were made, as are all deposits from water, horizontal. But the strata are now seldom found in a horizontal position. They are broken, and upturned, and inclined at various angles with the horizon by volcanic action. In many places they have been rent asunder, and the fissures thus made have been filled by matter from the interior, resembling the primary crystalline rocks. There are also rents, both in the stratified and unstratified primary rocks, filled up with veins of metallic ores, which must have been poured in while in a melted state. Sometimes immense rents and fissures in the primary rocks are filled with what geologists call a dike of trap rock. This trap rock is sometimes called, in this country, greenstone, and in Europe, basalt. It is evidently a species of lava, thrown up from below the crust, breaking it, and forcing the parts asunder, and spouting into every crack and crevice. I observed a remarkable one of these dikes in a granite ledge on the shore of Penobscot Bay. It was fifty feet wide. How long it was I could not determine. I traced it in one direction until it disappeared beneath the soil, and in the other till it was lost in the sea. The evidence that the two edges of granite ledge, now pressed by the dike fifty feet asunder, were once in contact, amounted to demonstration. This is in a region where there are no signs of any volcanic

mountains. Whatever volcanic power existed must have been generally active all over the region. Such dikes, of every size, from the width of a barley-corn to fifty feet, may be observed everywhere in the primary ledges of New England.

There are no organic remains in primary rocks, no vestiges of plants or animals—not one. The earth was then in no condition for living beings. It was too hot. Nothing, not even the salamander, could live in melted rock and burning lava. No traces of life are found in the stratified series, though they must have been formed after the crust had lost its high temperature. The time of living beings had not yet come.

We have already referred to the displacement and upturning of the strata of rock, after it had been deposited horizontally. I have never seen the strata of any slaty rock horizontal east of the Alleghany Mountains. In New England every thing is upturned. The strata lie at almost every angle, from 10° to 90° . In traveling over the country, you will often pass what is called an anticlinal ridge. You will pass for miles over the edges of strata inclining or dipping to the south, and then for a long distance they dip to the north. It would seem, that after the strata were deposited horizontally, volcanic agency, acting along a line, with force insufficient to elevate a mountain range, cracked the crust, and canted or lifted up the strata on each side of the line of action, and left them standing in an inclined position.

In the Mississippi valley, at least in this part of it, the strata all retain their original horizontal position, proving that the strata were here deposited since the cessation of extensive volcanic action.

It is evident that time of unknown, of unmeasured length, must have been occupied in the formation of the primitive series. A melted mass was cooled down, crystalized, and formed into a solid crust. The surface of this crust was

slowly worn away by the atmosphere and the waters, and the particles deposited from the sediment of the waters in stratified rock of unknown thickness. The strata were then broken and upturned by volcanic agency acting over an immense surface, but, like lightning, accumulating in certain lines. Time was then allowed for things to settle, become stable and firm, before the revolution of the next great period.

399. *Period of the transition formations.*—The series of rock immediately covering the primary, described in the last section, occupying the intermediate space between the primary and great secondary series, is called the transition series. In this series vestiges of life first appear, and geologists conclude, that during this period the earth was slowly passing from an uninhabitable to an inhabitable state, and so they call it the transition state. The series consists principally of slate, what is called graywacke, and limestone. The slate is generally called argillaceous, or clay slate. There can be no question in the mind of any one, who will examine a quarry of slate, that the clayey material of which it is composed was deposited by water at the bottom of seas, in thin layers, and afterward hardened by heat, as explained in section 333.

The graywacke is a slaty rock, sometimes partaking of the nature of sandstone, with angular fragments of other rocks imbedded in the mass. In many parts of the globe limestone abounds in this series, and in other places it is wanting. This series of rock is but slightly crystalline in structure. It was evidently deposited from water. It would appear, from observing the character and position of this series, that after the primary series, constituting a crust, was formed, the volcanic influence for a long time ceased to act. The earth had rest, and was quiet. The globe was covered with water. The action of water on the rocky bed prepared materials for a new series of rock out of the ruins

of those previously formed, and hence we have the various slaty rocks, which form an intermediate layer between the primary and the secondary series.

We do not know that this series encircles the globe, but we think it does. It has been found in every region yet explored. It varies greatly in thickness, being in some places but a few feet thick, and in others immeasurable. During this period, as it would seem from the evidence afforded by the vestiges of organic life, which the inspection of rocks will detect, God first, so far as earth is concerned, put forth his power in the creation of living beings. Of vegetable remains there are very few, and those principally sea-weeds. Of animals there are several species. They are principally corallines, star-fish, molusca, and a few specimens of fishes. They are all marine animals. Some of them, as the terebratula and trilobite, seem to have been universally diffused over all parts of the world. Other species are limited to particular localities. All the species and most of the genera became extinct at the close of this period. Of some, the genera continued through all the upper formations. The existence only of the remains of sea-weeds and marine animals proves, that during this period there was no dry land; and the total disappearance of all the species and some of the genera at the close of the period, proves that the earth underwent then such revolutions and changes as destroyed all the organic beings then existing. Such revolutions were frequent in the early history of the globe. Species of plants and of animals were created and adapted to the condition of the earth. They had their day, and fulfilled their destiny. When the condition of the earth changed there was no longer any use for them. The species perished, and in the next period new species, and often new genera, were created, and adapted to the new condition of the earth.

400. *Period of the secondary formations.*—We now approach a most important period in the history of the earth.

The secondary series of rock includes the coal measures, sandstones, and limestones.

In this series are found organic remains most astonishing, both from their number and magnitude.

As this series is very extensive, and must have occupied in its deposition a very long time, and as there are indications of several changes and revolutions on the surface of the earth during the period, we will describe the various classes of the series as they usually lie, with the organic remains they include.

101. *The coal series.*—The coal formation lies immediately above the transition rocks. Some geologists include it in the transition series, others in the secondary, and others again consider it as lying between the two, and properly belonging to neither. The coal formation is of vast extent, covering immense fields in Europe and America. It varies in thickness from a few inches to several thousand feet. It abounds in the remains of plants. Indeed, nearly all geologists believe coal to be wholly of vegetable origin.

There are a few facts, derived from observing the coal formation, to which we will call particular attention.

(1.) We have seen, that in the transition series all the plants and animals are marine. In the coal there are very few animals, and all or nearly all the plants are such as evidently grew on dry land, or in marshes. Therefore, the earth must have undergone such changes as adapted it to produce terrestrial vegetation. The sea had retired to its bed, and the dry land had appeared.

(2.) The temperature of the earth must have been at that time very hot, and nearly uniform in all latitudes. The plants are all tropical, such as grow now only in the torrid zone; and they are all of the same kind, though taken from widely distant coal mines—from Greenland, from England, and from the United States. They are not the same species in every mine, but the same class, all belonging only to a

hot climate. This would indicate that the earth, in those days, depended for its temperature less on its position with regard to the sun than on other causes. Probably the influence of central heat was yet powerfully felt.

(3.) A long, very long time, must be allowed for the accumulation of such immense and exhaustless quantities of vegetation. When, where, and how could such masses of trees and plants, as are gathered in the coal mines, grow?

(4.) There is evidence that the time when the coal formation ceased was marked by great volcanic disturbances. The coal beds are broken and dislocated by numerous dikes of trap. Probably the vegetable matter forming coal was first buried beneath the waters of the sea, and then subjected to intense heat. By this heat the carbon of vegetation might be made to combine with the hydrogen of the water, and form the bitumen, which abounds in our western coal.

402. *How fossils are preserved.*—Before proceeding farther, I should explain how fossils are formed and preserved. I ought to have done it in the article on transition fossils, but it did not then occur to me.

When an animal or vegetable is left exposed to the open air, it putrefies and is decomposed into its constituent elements, a part of which escape in the air, and a part lodge on the ground. When it is covered up by mud and water it decomposes more slowly, and as fast as each particle of flesh or wood is set free by decomposition, its place is supplied by a particle of lime, or sand, or whatever mineral matter the water may contain. In this way a perfect cast of the animal or vegetable may be formed. Not a particle of animal matter may remain, but yet the perfect shape be retained. In some cases the shell of animals, being originally lime, remains precisely as it covered the creature while living. Of vegetable remains we sometimes find mere

impressions of the plant on the rock. At other times we find the bark preserved, and occasionally portions of the wood. In the upper series of the secondary and the tertiary rocks, we find the bones and skeletons of animals well preserved.

The most of the organic beings, found in a fossil state, seem to have lived and died in the very places where they are now found. They do not appear broken and crushed, as if transported from a distance, but retain their perfect shape. Some of the plants in coal mines retain the tender limbs and delicate leaves in the most natural form. In some parts of the secondary series, especially in the chalk formation, marine animals and fish are preserved so perfectly, that it would appear as if, while alive and swimming, they were suddenly overtaken by a hot current of paste, killed on the spot, and entombed and embalmed.

The process of petrification is now going on in some localities. A piece of wood placed in water decays, and the place of its vegetable matter, as it disappears particle by particle, is supplied by lime or sand, and the appearance is as if the wood were really changed into stone.

403. *Deposition of sandstone.*—Immediately above the coal lies, in most parts of the world yet examined, a deposit of sandstone, conglomerates, marl, and interspersed beds of limestone. Observation induces geologists to think that the sandstone, which is the principal deposit of this group, was formed out of material furnished by the violent breaking up and disintegration of the older rocks, particularly the greenstone and other volcanic rocks, which were thrown up from below and protruded through the crust, and which are very easily decomposed. Fragments of other rocks are often found imbedded in sandstone. Some specimens of sandstone consist entirely of fragments of other rocks, cemented in a species of conglomerate by a silicious or calcareous cement.

From the examination of the sandstone series, we are induced to believe,

(1.) That the commencement of its formation was marked by great revolutions of the surface of the earth, for all the animals and plants, living during the coal period, disappear from the sandstone, having, probably, been suddenly killed.

(2.) That during all the time of the sandstone deposition, revolutions, by flood and by fire, were frequent. Volcanic action alone could break up the crust, and protrude the trap. The slow action of water must wear away and comminute the broken fragments. The action of deep and quiet seas was necessary to allow the materials of the deposit to settle in the position in which it originally lay. Renewed volcanic action was necessary to harden the deposit into stone, and to elevate the strata from their inclined position.

Frequent alternations of very coarse and very fine sandstone, evince the recurrence of frequent revolutions. The scant supply of fossil remains, either of animals or plants, in sandstone, would indicate that the condition of the earth at that time was unfavorable to the multiplication of living beings. Long periods of undisturbed repose seem indispensable to the accumulation of vegetable or animal remains.

404. *Secondary limestone.*—Above the sandstone are found several varieties of limestone. One variety is called the *lias*, or horizontal limestone. Another is called *oolite*, or *roestone*, from its resemblance to a conglomerate mass of fish-spawn. This limestone series occurs of great thickness in some parts of Europe, but has not been found in America. It is supposed to be wanting on our continent. Probably during the time of its formation in Europe, our continent was in a state of repose.

405. *Remarkable organic remains.*—In the secondary limestone series are found the most astonishing specimens of organic remains ever seen by mortal eye, or imagined by

mythic part. They generally resemble, in shape and appearance, the family called by naturalists the saurian, or lizard tribe, of which the alligator and crocodile are species. Large numbers have been discovered in the limestone quarries of England, and their skeletons arranged by naturalists. One family, or genus, of which some seven or eight species have been discovered, is called the ichthyosaurus, or fish lizard, from its combining the characteristics of the crocodile and the fish. In some specimens found, the eye was fourteen inches in diameter, the jaws six feet long, and containing one hundred and eighty teeth; and the backbone consisted of one hundred joints. It lived in the sea, and moved rapidly through the waters by finny paddles.

Another genus, the plesiosaurus, had a body twenty feet long, a head like a lizard, a neck of thirty joints, and teeth resembling those of a crocodile. It lived in the water, and breathed air like the whale.

The megalosaurus had a body fifty and legs six feet long. This animal lived on land.

The iguanodon had a body seventy feet long and fifteen in girth. Its thigh was two feet in circumference. It had a big horn like a rhinoceros. There is evidence from its structure that it was herbivorous, proving that the globe then furnished dry land and vegetation.

The pterodactyl is pronounced by Cuvier the strangest animal of the ancient world. It had the body of a lizard, with excessively-long legs, formed, like the bat's, to expand into a membrane, by which it was enabled to fly, and a long beak armed with sharp teeth. Its covering was scales. Just think of a scaly bird! What a strange animal!

Such is an imperfect outline—a faint attempt at description—of a very few of the wonderful creatures that lived on earth at the time the secondary rocks were deposited. Their remains have lain entombed deep in the earth for thousands of ages, till the operations of mining, together

with natural causes, have exposed them to the eye of science. They lived for their allotted period, and sported along the shores of the ancient globe—then passed for ever away. In some mighty convulsion of earth they all perished. Not one was left to tell the story. Among all the tribes of modern animals, whether inhabiting land or sea, there is not found one resembling them. They are gone—all gone—for ever gone.

406. *Chalk series.*—In England and many parts of the eastern continent is found, immediately above the secondary limestone, a stratum of chalk, in some places two thousand feet thick.

It would appear that, between the time of depositing the secondary limestone and the chalk, there occurred some mighty revolution, destroying all the monstrous reptiles of the earth; for not one of them is found in the chalk. There are, however, numerous organic remains in chalk; but, instead of being herbivorous, as in the last period, they are exclusively marine. This proves that, in the revolution, the dry land had sunk, and the sea covered the earth. The surface of the chalk is deeply furrowed and prominently ridged, showing that, after it was deposited, there occurred a period of considerable time, during which the sea continued to cover the earth, and, by its rolling billows, furrowed out the deep depressions in the rock.

407. *Period of the tertiary formation.*—The tertiary series of rock consists of clay, sand, gypsum, and common soil. Before the discoveries of Cuvier these were considered mere superficial deposits of gravel, sand, and clay; but as there were found in these deposits the bones of a higher order of animals than had been found in the secondary series, and different from any now living, and as it was further ascertained that the deposits were general, extending over the whole earth, geologists gave the series a distinct name—tertiary.

Later investigations prove that the tertiary deposits do not all belong to the same time, but that there are at least four distinct periods, in the order in which the deposits succeed, indicated by changes in the nature of the organic remains imbedded in them. Inasmuch, however, as the distinctions made by Deshayes and Lyell between the first and second and the third and fourth periods are founded on peculiarities in fossil shells, which we cannot well describe without specimens before us, it will be sufficient for our purpose to regard the tertiary formation as occupying, in their formation and deposition, two periods, marked by the successive existence of peculiar and interesting animals of the higher orders.

408. *Age of the pachydermata.*—In the extensive quarries of gypsum near Paris the workmen frequently dug out the bones of unknown animals. In the mind of the uneducated laborer they excited little attention, and were thrown away. The fact, however, coming to the knowledge of Cuvier, he undertook to examine the matter. The result of the examination astonished himself and the world. He discovered upward of fifty species of animals not now known on earth. They all belonged to the order which naturalists call the pachydermata, or thick-skinned, of which the horse, the hog, and the rhinoceros are examples. They were not, however, horses, nor hogs, nor any thing else now living on the globe. Cuvier's own account of the manner in which he succeeded in reconstructing these strange skeletons is peculiarly interesting: "I found myself," says he, "as if placed in an immense charnel-house, surrounded by mutilated fragments of many hundred skeletons, of more than fifty kinds of animals, piled confusedly around me. The task assigned me was, to restore them all to their original position. At the voice of comparative anatomy every bone and fragment of bone resumed its place. I cannot find words to express the pleasure I experienced in seeing, as I

discovered one character, how all the consequences which I had predicted from it were confirmed. The feet were found in accordance with the characters announced by the teeth; the teeth in harmony with those indicated beforehand by the feet; the bones of the legs, and thighs, and every portion of the extremities, were found set together precisely as I had arranged them, before my conjectures were verified by the discovery of the parts entire. In short, each species was, as it were, reconstructed from a single one of its component elements."

Most of the animals whose remains are discovered in this division of the tertiary formation belong to the classes that usually live on herbs, about lakes and marshes, such as the hippopotamus. All the species are now extinct, but some of the genera are still found on the earth.

409. *Age of the mastodon.*—All the species of animal belonging to the first division of the tertiary rock, and described by Cuvier, perished in some great revolution occurring between the deposit of the lower and upper tertiary formation. Instead of them there seems to have been created, to occupy the earth during the later tertiary period, the race of mammoths and mastodons. The fossil mammoth is found in the north of Europe and Asia in immense numbers. A brisk trade is yet driven in the ivory obtained from the teeth of these extinct animals, of whose existence we should never have known, had not their bones been discovered.

The mastodon was a native of North America. He resembled the elephant, but was much larger. His bones have been found in New York, and in several places in the western states. He was a magnificent animal, well proportioned to the sublime mountains, great rivers, and illimitable prairies of North America. He had his day; probably enjoyed it, and passed away. At the close of the period destined to his species some terrible revolution passed over

the earth, rendering it formless and void; and, in that revolution, the great mastodon, with every other animal on earth, perished.

The gradual preparation of the earth for man.—A review of the facts we have presented will reveal the beautiful order in which God was pleased to bring about the preparation of the earth for the residence of man. During the first period it was but a mass of incandescent, molten matter. The great sea covering the earth rolled, and boiled, and flowed, not with life-sustaining waters, but with molten rocks and burning lava. This boiling sea cooled down, its waves subsided, and its surface became solid earth. In the second period—the time of transition—the solid rocks were broken up, the fragments ground and comminuted, and a soil formed, on which might flourish the luxuriant vegetation of a tropical clime.

In the third period vegetation proceeded with astonishing luxuriance. Accumulated masses of vegetable matter were gathered, a thousand feet thick, in the bosom of the valleys, and were changed, by a foreseeing power, into coal, to supply the wants of human beings not then created, existing only in the mind of God. During the latter part of the period immense deposits of salt were formed, furnishing a supply for men and for animals for ever.

During the fourth and last period the soils suitable for existing plants were formed, and preparations were made for fitting up a home for man.

411. *Progressive development of organic life.*—The same beautiful order is exhibited in the successive creations of animals. First came the poor little shell-fish, endowed with scarcely a sense, fixed to a rock, and hardly alive. Then came the gigantic saurians, before which all the whales that Nantucket sailor ever pursued would flee in dismay. After these came Cuvier's anoplotheria, cheropotami, and lophiodonta. Last of all came the mastodon, his voice

echoing through the magnificent forests of the west, and his foot shaking the earth on which he stood.

412. *Design of change and revolution.*—We have seen indications of wonderful revolutions in the condition of the earth; the passage of the primary crystalline rocks from a fluid to a solid state; the deposition of stratified rocks, at the bottom of the ancient seas; the elevation of both the stratified and the unstratified rocks from beneath the sea, at successive intervals, to form continents and islands; violent inundations, and the decomposing power of atmospheric agents, producing partial destruction of the lands, and forming from the ruins extensive beds of gravel, sand, and clay. We have also seen, during all the periods, indications of volcanic action, elevating mountains, sinking portions of the earth for the bed of the sea, upturning and tilting at various angles, the horizontal strata, and protruding dikes of lava through the various series of rock.

The design of these revolutions was evidently the better to prepare the earth for the purposes of man. Had all the strata remained in a horizontal position, each series encircling the earth, like the concentric coats of an onion, man could never have seen but one kind of rock. The metals of iron, lead, silver, and gold, the deposits of coal and salt, would never have been discovered, or if perchance discovered, would have remained beyond his reach.

Not only the agency of heat, but of water, is seen in preparing the earth for man. By deluges and currents the soils have been formed and duly mixed, meet to produce the grains and grasses most valuable to man.

413. *Time.*—To bring the globe from its condition during the period of the primary to that at the end of the tertiary formation, to carry it through all the revolutions and changes indicated by appearances, and to create, bring to maturity, and destroy the innumerable races of beings, whose remains are left in the rocks of the globe, would

require a long time. A few days, a few years, a few thousand years, was insufficient. If historical and astronomical data be wanting, or unavailable, time can be measured only by succession of effects. Measuring geological time thus, it appears all but infinite. We cannot talk of years nor centuries. We must speak of periods—of great cycles.

414. *Consistency of geology with revelation.*—We now return to the question with which we commenced this lecture. We will examine the account the Bible gives of the creation, and see if it be consistent with the facts we have presented, and the theories we have proposed, on geology.

The account of Moses will be found, on careful examination, to embrace three points, or leading facts. These are,

- (1.) The original creation of the earth in the beginning.
- (2.) The condition of the earth at some time subsequent to its creation.
- (3.) The detail of the work of six days in creating plants, animals, and man, and in effecting the necessary arrangements of the earth and atmosphere for the purposes of the occasion.

415. *Creation of the earth in the beginning.*—"In the beginning God created the heaven and the earth." Two facts are here revealed:

- (1.) That matter was created by God. It was not eternal, nor independent of the Almighty, as the ancient philosophers vainly dreamed; but God, of his own will, and by his own power, and in his own wisdom, created it. In what state it was when first created, whether gaseous, liquid, or solid, we are not informed. Most philosophers think it was at first gaseous, then fluid, and lastly solid. We understand this verse of Genesis to imply, not only that God created, in the beginning, matter, but that he placed it in form—in the form of planets and suns. It

might, however, be in a gaseous condition, and still have such shape as to be properly called heavens and earth.

(2.) That the heaven and the earth were created "in the beginning." That might be a long, very long time ago. "In the beginning!" I can imagine no period beyond "the beginning." It goes back far as my mind can run.

Geological science confirms both these facts. No geologist pretends that matter existed from eternity, or could attain existence but by the all-creating power of God. As to time, we have seen that geology requires the creation of the earth to be placed back ages and ages before the age of man.

416. *Formless and uninhabited condition of the earth.*—"And the earth was without form, and void." On this assertion of revelation we have two inquiries to make: the one is, what is meant by the formless and void condition of the earth? and the second, at what period of time was that its condition?

The expressive phrases "without form," and "void," depict a wasted, desolated, revolutionized condition of the earth's surface, and the absence of living beings. That this is the true meaning of these Scripture phrases, you must see by turning to the fourth chapter of the prophecy of Jeremiah, in which he uses the very same words, in the particular sense I have given: "I beheld the earth, and lo, it was *without form, and void*, and the heavens, and they had no light." As if more fully to explain his meaning, and to prove the interpretation given, he immediately says, "I beheld, and lo, there was no man, and all the birds of the heaven were fled. I beheld, and lo, the fruitful place was a wilderness, and all the cities thereof were broken down at the presence of the Lord."

Therefore, whenever "the fruitful places of the earth" become incapable of producing sustenance, and the dwelling places of living beings are broken down, and there has

been a sweeping away of living beings, the earth, in Scripture language, is "without form, and void." As to the time when this was the condition of the earth, geology teaches us that precisely such a condition of things existed at the close of the tertiary period. A great revolution had passed over the earth. Its pleasant places were desolate, its inhabitable parts broken down, and all its living creatures passed away. Ruin had driven her ploughshare over the face of nature, and buried in its furrows even the gigantic mastodon. We therefore see, that the first and second verses of Genesis refer to periods at a vast distance apart. The first refers to "the beginning," or the creation of matter; the second, to the close of the tertiary period. Between these two points of time, and the occurrence of the two facts only, which the Bible reveals, intervene ages unknown, in which transpired all the phenomena indicated by geology. Of these intermediate events the Bible says nothing.

To the cursory reader it may seem strange, that the Bible should pass over so important facts unnoticed. But if you will follow me, I will show you that both in the omission of all allusion to these facts, and in the form of narrative adopted, this passage of Scripture conforms strictly to the usage of the inspired writings.

The traveler wending his way over a mountain region, standing on the summit of some lofty range of the Alps or Cordilleras, sees before him only the tops of the hills, and the prominent outlines of the country. His eye glances from summit to summit, reaching far in the distance. Many a beautiful vale, and shady dell—many a dark ravine, and frightful chasm, escapes his eye. In much the same way range our thoughts over the past. The prominent facts, jutting points, and important periods of history only occur to the mind. Such is the law of association of thought. Events are associated either by resemblance or contrast. In the same way are events of the future associated in the

mind of the prophet. The inspired writer of the book of Genesis looked, by gift of the spirit of Omniscience, into the past, as the prophet of God would look into the future. The only two events of the past, interesting to man as a moral being, were associated in the mind of the man of God by a natural law of mind. To these two facts, or events, he merely alludes, as if the latter followed the former in immediate succession. Let us see if there be not in the holy Scriptures other examples of the same usage.

In the first chapter of Exodus, Moses, after saying that Joseph died, and all his brethren, and all that generation, and that the children of Israel increased and filled the land, immediately proceeds to say, "Now there arose up a new king over Egypt, who knew not Joseph." The accession of the new king is separated in the history from the death of Joseph only by a slight allusion to the rapid increase of the children of Israel, and we should naturally suppose the two events occurred within a short period, and the intervening time was marked by no important events. Yet we learn from other parts of the Bible, that several centuries passed away, between these two events, so closely related in the narrative. Late investigations in Egyptian history, founded on the hieroglyphic inscriptions on the monuments of the Nile, show that, between the death of Joseph and the time of the new king, Egypt suffered radical revolutions. The dynasty, or race of kings, who governed the land in Joseph's time, was conquered and expelled from the country, and a new dynasty took possession.

The history of the wars, and battles, and overwhelming revolutions that occurred, is totally overlooked by the inspired narrator. These facts of Egyptian history were not deemed a necessary part of divine revelation. They are omitted, and left for us to find out by our own researches.

In the 24th chapter of the Gospel by Matthew is recorded a prophetic account, as given by Jesus Christ, of

events connected with the destruction of Jerusalem. In the very next chapter the narrative proceeds, as if in continuation, with an account of later events, terminating in the second advent of Christ, and the general judgment. The end of the world, with the judgment of the last day, is connected so immediately with the destruction of the city of Jerusalem, as to appear as if the one event would follow the other without material intervention of time or other events. So closely are the two events related in the narrative, that the early Christians were misled, and really expected the second coming of Christ, the resurrection of the dead, and the general judgment, in their day.

But what a series of events has already transpired since the city of Jerusalem was laid in ruins by the forces of the Roman empire! And what a series is still to transpire before the final consummation of human history, when the great archangel shall announce the end of time, and call the nations to judgment! All the astounding events of the last eighteen hundred years, and all those yet to occur while time shall continue—events of *human* history, in comparison with which the history of volcanoes, and deluges, and saurians, and mammoths, is of no account—are utterly overlooked and wholly omitted in the narrative.

Such, then, appears to be the usage of inspiration, the law of revelation. Events related by contrast or similarity, rather than by time, are associated together. Events of moral interest are revealed. Those of mere political and scientific character are omitted, and we are left at liberty to find them out by study.

I am aware that this interpretation of the first and second verses of Genesis, separating the original creation of the earth, revealed in the first verse, from its formless and void state, revealed in the second, by so many unknown ages of time, occupied by such startling revolutions, differs materially from the popular notion of the Mosaic record. But

though I adopted this interpretation from my own reflections, many years ago, yet I find, by later reading, I am by no means alone. This interpretation of the inspired records is one of those truths which men of science and reflection are likely to adopt independently of each other. The same facts, and the same course of reasoning must lead men of well-balanced minds to the same conclusion. From the authority of Dr. Wiseman, it appears that some of the early Christian fathers adopted this interpretation. St. Gregory Nanzianzen supposes an indefinitely-long period between the creation and the first ordering of all things. St. Basil, St. Cæsareus, and Origen, account for the creation of light prior to that of the sun, by supposing this luminary, indeed, to have existed before, yet so as that its rays were prevented, by the dense atmosphere, from penetrating to the earth. This opinion of these ancient Christian men, on the subject of light, appears to me quite philosophical. It supposes the darkness, which was on "the face of the deep," at the time of the formless and void appearance of the earth, was caused by dense vapors in the atmosphere, such as might be expected after such revolutions, as we have supposed marked the close of the tertiary period; that the light which appeared at the word of God, "let there be light, and there was light," was not an actual appearance of the sun, but such as would appear from a partial clearing away of the vapors, the atmosphere appearing in the condition popularly called overcast; and that the final clearing away of all the clouds and vapors, and exhibiting to full view the sun, placed in the firmament of heaven, marking for man the days, seasons, and years, was the work of the fourth day, as described from the fourteenth to the nineteenth verses.

It is somewhat remarkable that this interpretation was adopted by the fathers long before geology was known.

Of the moderns—men good and great—devout men and true men—who have adopted the interpretation for which

we contend, it is sufficient to mention the names of Wiseman, Chalmers, Buckland, Rossenmuller, Whewell, Bell, and Herschel.

417. *The six days of creation.*—The theory we adopt supposes the six days of creation to have been occupied in dispersing the vapors, and clearing away the clouds, that had gathered over the earth during the last tempest of revolution; in separating the land and the waters, which the late revolution had mixed and confounded together; in creating vegetables and animals, in place of those which had been destroyed in the general catastrophe; and last of all, in creating man, who had never yet existed on the earth.

There is no difficulty in supposing the time occupied in this work of renovation and creation to be six natural days, marked by the revolution of the earth on its axis. Indeed, there seems a great moral design in doing the work in six days. It was to give origin and a place to the Sabbath, which occupies so prominent a position in the moral history of humanity.

The vegetables and animals which God created in those six days were the species which now exist on the globe. All that had been created before had perished in the last revolution. Not any of the old species were reproduced in the new creation, except, perhaps, a few of the shelly animals, inhabiting the waters. The plants, trees, birds, and terrestrial animals were all of new species, and generally of new genera. The number of species is not supposed to have increased since that time. Varieties have sprung up, and unnumbered individuals have appeared, but the well-marked and distinct species remain the same. No new ones have been created, since God rested from his works on the first Sabbath, nor is it probable any more will be created.

While geology demands, and revelation allows an indefinitely-long period of time since the first creation of matter

in the beginning, yet neither science nor revelation admits of more than about six thousand years since the new adjustments, and new creations, and the establishment of the present order of things. In the age of the earth as it now is, of the species of animal at present existing, and of the race of man, history, geology, astronomy, and revelation agree.

418. *Age of the world.*—We will present a slight view of the nature, and a brief summary of the principal of the proofs from geology, determining the age of the world, meaning thereby the world as it now is, with its present continents, islands, and seas, modified and changed only by the equable action of causes now in operation.

Winds, rains, frost, the agency of running water, and the action of the sea, are constantly producing changes on the surface of the earth; steep eminences are broken down, and debris collected at the base; rivers are depositing along their banks alluvial soil, and accumulating matter, forming deltas at their mouth; vegetable mold is accumulating on the surface of the earth; the land is worn away by the sea, and sand-banks, moved by the winds, are annually gaining ground. The progress of any of the changes we can measure for a series of years. Thus we can tell how much land has been gained from the sea by the accumulation of matter carried down by the river, at the mouth of the Mississippi, the Nile, or the Ganges, during a century or any other limited period, during which observations have been made. We can determine how far a sand-hill has moved onward from the sea, or from the desert of Lybia, during a series of years. We can determine how many inches of alluvial matter is deposited in ten or twenty years on the bottom lands of any river.

We can easily measure the amount of any of these changes since the beginning of them. We can tell how many acres of delta have been formed at the mouth of the

Mississippi, or the Po, or the Nile; how many miles the sands of the Lybian desert have moved from their original bed; and how many feet of alluvial matter are accumulated along the banks of the Wabash, the Ohio, or the Danube. Inspection and measurement may easily determine, with great accuracy, the quantities in each of these, and any similar cases.

Having then ascertained how much has been effected since the present order of things began, since the land and sea assumed their present local and relative positions, since the present rivers began to flow, and since the present forests began to shed their leaves on the ground; and having, also, ascertained how much is effected annually for a series of years, we can easily determine, within a reasonable degree of accuracy, the age of the world in its present relations.

To go into the detail of this class of facts, would extend this lecture to an unreasonable length. The subject is ably treated by Cuvier in his discourse on the revolutions of the surface of the globe. The evidence is clear, that the present order of things cannot have been in existence longer than about six thousand years. A longer period would inevitably have produced, from the gradual agency of physical causes, much greater modifications and changes than appear. The Scripture chronology is, therefore, sustained by geology.

LECTURE XVIII.

THE DELUGE.

Scripture account of the deluge—Historical proofs of the deluge—Geological proofs of a general deluge—Proofs of an early deluge—Proofs of a recent deluge—Identifying rocks—Bowlders—Diluvium—Direction of diluvium—Diluvial grooves—Transporting power of water—Transported diluvium not the result of causes now in operation—Physical cause of the deluge—Conclusions from the diluvial argument.

419. *Scripture account of the deluge.*—The Bible records a great deluge which swept over the earth, some sixteen centuries after the creation of man, and during which the waters rose over the high hills of the earth, and, with the exception of one family of persons, and a pair of each species of animal, preserved in an ark, utterly destroyed all terrestrial animal life on the globe.

We will endeavor, in this lecture, to present some evidence from history, but more from geology, confirming the truth of the Scripture narration.

420. *Historical proofs of the deluge.*—Such a catastrophe as that happening in the time of Noah would not soon be forgotten among men. The traditionary legend would go down, from generation to generation, for a long succession of ages; and the early records of literature would surely contain allusions to it; and, as we should naturally expect, the account of the deluge is ingrafted into the annals of all nations.

The first notice we find of the event, except the account in the Bible, occurs in the Greek poets. Pindar, who lived five centuries before Christ, alludes to the tradition, and to the arrival of the survivor, whom he calls Deucalion, on Mount Parnassus; Plato, the philosopher, who lived a century later, speaks of the deluge as a general event—a completely-universal deluge; Apollodorus, who lived later than Plato, in referring to the deluge, gives Deucalion an

ark as a means of safety; Plutarch mentions the doves by which he endeavored to ascertain the abatement of the waters; and Lucian alludes to the animals of every species, which he had embarked with him. These writers knew nothing of the Jewish Scriptures, and must have derived their notion of the flood from the popular tradition delivered down from age to age.

It appears from Maurice's Hindostan, and other works on Asiatic researches—authorities which I have not seen, but to which Townsend refers in his notes—that similar traditions were current in Asia. Faber, also, in his *Origin of Pagan Idolatry*, discusses the universal traditions of the deluge, and traces several rites, ceremonies, festivals, and emblems to the traditional history of the circumstances of that great event.

The force of this argument, when fully presented by copious illustrations, is very great. If a nation or tribe of people possesses a tradition of any historical event, it is considered pretty good evidence that an event, very similar in all essential respects to the traditional one, did really occur. And if a great number of nations or people is found to have a similar tradition, it is clear proof that the event was general. If the tradition be universal, as in the case of the deluge I think is the fact, then the event must be incontestibly universal.

421. *Geological proofs of a general deluge.*—But, to my mind, the evidence from tradition is much less weighty, than that which arises from actual inspection of the marks, which the deluge has left on the surface of the earth. Were the Scriptures wholly silent on the subject, and were no tradition of the event found in the literature of a single nation on the globe, the geologist would *know* that the earth must, in ancient times, have been swept by some great and universal deluge. Indeed, so evident are the marks which the waters have left of their action, that most geologists believe

there may have been, in the history of the earth, repeated deluges. Only one, however, is supposed to have occurred since the present order of things. I will venture to say, that any man of respectable attainments in geological science, who will carefully examine the face of the earth in the Mississippi valley, and in New England, will inevitably come to the conclusion, that there have been at least two deluges—one before the deposit of the tertiary formation, and the other long since.

422. *Proofs of an early deluge.*—Examine the appearance of the earth thrown out in digging wells on any of the ridges of southern Indiana. You will observe, below the regular layers of stratified earth, a confused mass of gravel, rounded and water-worn pebbles, and sometimes large rocks. This often occurs twenty or more feet below the surface of the earth. The pebbles and rocks are not all limestone, which is the only rock found naturally in place in this neighborhood, but fragments of flint, granite, gneiss, and greenstone, rocks which are not natives of the Wabash valley. Now, it should be borne in mind, that rocks are not originally made in detached and small masses, but in ledges of great extent. Nor were they originally rounded in shape. Wherever you find a round rock, be sure it has suffered from the action of running water. These water-worn pebbles, therefore, and large stones, found many feet below the present surface of the earth, of a kind of rock different from any of the native ledges of this region, must have been brought here from a distance by a deluge. They could not be broken from the primitive formations immediately below the spot, for if there be a deposit of granite and gneiss in this region for below the surface, it is everywhere covered by limestone. This deluge must have occurred in very early times, long before the six days of the creation, because the diluvial deposit is covered by regular layers of secondary and tertiary formation.

The same kind of evidence may be observed almost anywhere in New England. Large deposits of diluvium, and immense masses of loose and water-worn rock, are found so far below the surface, so far below tertiary deposits, as to prove incontestibly that great deluges must have swept over the earth long before man existed.

But is the recent deluge whose march we are to trace, the deluge of tradition—of Scripture history; a deluge which passed over the earth since it was renewed and changed from its formless and void state; a deluge whose marks are left above the tertiary formations; a deluge whose ravages may be seen on the very surface of the globe?

423. *Proofs of a recent deluge.*—The proofs of a recent deluge are found in the existence of soil, pebbles, gravel, and large rocks, in places where it is evident, from the difference between them and the regular stratified formation of the country, they could not have been originally deposited.

424. *Identifying rocks.*—There is no difficulty, for a practiced eye, in identifying rocks. We may pick up a fragment of granite, or slate, or limestone, and by comparing it with several quarries of granite, or slate, or limestone in the neighborhood, determine from which particular one it came. It is as easy to distinguish granite, and limestone, and sandstone from each other, as to distinguish white men from black. It is as easy to distinguish specimens of the same kind of rock, belonging to different localities, as to distinguish families from each other. We can determine usually by the general appearance, on the slightest examination, to what ledge any loose fragment of rock is to be referred. One who has never practically attended to mineralogy and geology, would hardly believe how rocks may be known apart by their looks.

425. *Boulders.*—Before going more fully into this sub-

ject, we must explain a few terms, which we shall find occasion to use. Loose and rounded fragments of rock, found on the ground, or imbedded in the soil, appearing different from the native ledges of the locality, and evidently brought there by some external force, are called boulders.

426. *Diluvium*.—These boulders, and all gravel, pebbles, sand, and soil, irregularly mixed together, exhibiting no appearance of stratification, and apparently swept along from a distance, and left in the place where it is now found, by the action of water, is called diluvium. Diluvium is found in all parts of the world. It varies greatly in thickness, and in general appearance. It is much more abundant in New England than in the west.

427. *Direction of diluvium*.—Go to the southern shore of Connecticut. Begin at the southwestern corner of the state, and travel along the southern tier of townships to the southeastern corner of the state. Observe, as you proceed, the character of the diluvial soil and the boulders. You will observe both differing from the character of the native rocks of the townships, lying in the ledges as nature made them. Return along the tier of townships lying next north, and you will find the diluvium and the boulders still differing from the native ledges in place, and perhaps, also, differing from the diluvium and boulders below. Going thus over each tier of townships in succession, you will not fail to find at last the ledges from which the boulders in the most southern townships were borne. A little farther north you will find the ledges from which the boulders of the second tier were torn, and you may thus trace the boulders of any place to their parent ledges somewhere north, or more generally a little northwest. Come up into the state of Massachusetts, and go over the tiers of townships in the same order, from the Berkshire hills to the Atlantic coast, and you will observe the diluvium and

bowlders still traceable to the north. Go into the state of Maine, where the deluge seems to have spent its force, and pursue the same course of examination, and you will find the diluvium and bowlders traceable in a northerly direction. In some instances you will find the parent beds a few miles, and sometimes a hundred miles north.

In a geological examination of Maine, I frequently found fragments of fossil limestone, of a peculiar character, containing abundant remains of the shell called *terebratula*. Maine is known to be a primitive country. Fossil remains are as much out of place there, as granite quarries in Indiana. I found a fine specimen of this fossil on one of the islands in the Penobscot Bay, and they were occasionally picked up in various places. On arriving at the Aroostook river, in the extreme northern part of the state, more than one hundred miles from the spot where we picked up the first of these specimens, we found, in its native place, the very bed of limestone from which all these specimens were evidently borne. There could be no mistake about it. The identity of character between the fixed ledge and the loose fragment was perfect.

While the general direction of the diluvium and bowlders is northerly, or a little west of north, there are places in which the direction is considerably varied. But all these variations are evidently caused by ranges of mountains in the neighborhood, which turned the direction of the waters. This proves that the present ranges of mountains existed at the time of the deluge. There is yet another evidence, both that the mountains stood in their present position at the time of the deluge, and that the waters covered their tops. Diluvium and bowlders are found on the very tops of the highest mountains. Professor Hitchcock found them on the tops of the mountains of Massachusetts, and specimens of the fossiliferous limestone, of which I have spoken, were found on the very summit of Mount Katahdin, nearly six

thousand feet high. I picked up one of them with my own hand, lying loose on a granite ledge, on that lofty summit, and it now lies on my table before me. No man ever put it there, for I doubt whether human foot had ever before stood on that distant spot, where the lone mountain rears its bleak and moody head high among the snowy clouds, and surrounded for a hundred miles with a dark and pathless forest, from which rises the smoke of no human habitation.

The same phenomena of diluvium and bowlders exist in every part of the United States, and of Canada, so far as I have personally examined, or have learned from reading travels and the results of scientific exploration. In our own western states bowlders are much less plenty than in New England; but they may be observed scattered almost everywhere about our fields. On some parts of the north-western prairies of Indiana they are strikingly numerous. There is a lot of them on one of the prairies on the Lafayette road, some fifteen miles south of the Wabash. The most of those I have examined in this neighborhood, are granite, gneiss, and greenstone, and are evidently strangers among us. In some situations they appear so evidently out of place, that the common people call them "lost" rocks, as though they had wandered away from home.

Transported rock and gravel are by no means limited to the American continent, but are found wherever examinations have been made; and the general direction is uniformly the same as in America, varying only from local causes, such as the shape of the country, and the position of the hills and valleys. There would not appear, so far as I can judge from English writers, so striking illustrations of diluvial action in England as in the United States; but examples of fragmentary rocks entirely out of their natural place, are by no means rare. Professor Buckland mentions that he found, among the transported gravel of Durham, twenty varieties of slate and greenstone, which do not occur in

place nearer than the lake district of Cumberland, northwest. He also notices a large block of granite, near Darlington, evidently from a ledge near Penrith, more than fifty miles northwest. Blocks of the same granite are found at Bernard Castle, at Tees, and at Sedgefield, places forty miles apart.

Professor Sedgwick notices, on the hills of Cumberland, bowlders and pebbles, which have been transported across the Solway Frith, from Scotland. He says that the "syenitic blocks of Carrock-Fell can be traced, through the valleys and over the hills of the mid region, to the very foot of their parent bed." He further remarks, that the blocks of trap granite, which cannot be confounded with other rocks in the north of England, have been rolled over the great central chain of England into the plains of Yorkshire, imbedded in the transported detritus of the Tees, and even carried to the eastern coast.

De La Beche states, that between the Thames and the Tweed, pebbles and even blocks of rock are discovered, of such a mineralogical character, that they are considered as derived from Norway, where similar rocks are known to exist.

Mr. Phillips says, in his geological illustrations of Yorkshire, that the rocks from which the fragments in the diluvium of that part of England appear to have been transported, "are found, some in the mountains of Cumberland, some in the Highlands of Scotland, and others in Norway. In proportion to the distance they have traveled is the degree of roundness they have acquired." In Scotland, and the isles north of it, occurs abundant evidence of diluvial transport, following the same general direction; so that De La Beche says the facts seem to warrant the conclusion, "that a body of water has proceeded from north to south over the British isles, moving with sufficient velocity to transport fragments of rock from Norway to the Shetland

Isles, and to the eastern coast of England; the course of such body of water having been modified and obstructed among the valleys, hills, and mountains, which it encountered, so that various minor and low currents having been produced, the distribution of detritus has been in various directions."

Proceeding to the continent of Europe, the same phenomena are observed. In Sweden and Russia large blocks of rock occur in great numbers, and no doubt, says De La Beche, can be entertained that they have been transported southward from the north. In Sweden the transported materials were observed by Brogniart to run in lines, sometimes inosculating, but having a general direction north and south. Similar observations are made by Count Rasonmouski on the transported blocks of Russia and Germany. He states the general direction to be from northeast to southwest, almost precisely that assumed by the diluvium in the state of Maine. He says the bowlders are very numerous between St. Petersburg and Moscow, and are evidently Scandinavian rocks. He remarks that they occur more frequently on the steep escarpments than on the plains, as if the hills caught them in their passage onward.

Proceeding southward, the course of the waters seems to have continued in that direction over the low districts of Germany, to the Netherlands, depositing in their passage huge blocks, which are proved, by their mineralogical composition, to have been derived from rocks known to exist in the northern regions. Among the mountain regions of the south of Europe, the diluvium is marked by such variations from its general direction as the broken face of the country might naturally lead us to expect. De La Beche, who has examined this subject very thoroughly and extensively, and who does not once allude to the Bible, is inclined to the opinion, that the distribution of the diluvium of the Alps, of the north of Europe, and of America, happened at one

and the same time, and is positive that the time was, geologically speaking, recent, inasmuch as the diluvium rests on strata of little comparative antiquity.

I have not at hand authorities to decide whether diluvium exists in Asia and Africa, similar in position and direction to that of Europe and America. I know not as satisfactory explorations have yet been made. Phenomena, however, so similar, over such immense extents as the continents of Europe and America, are sufficient evidence of a general deluge.

428. *Diluvial grooves*.—Sir James Hall, as quoted by De La Beche, considers the rush of waters over the land in Scotland to have left “traces of its course, in the shape of furrows, which the transported mineral substances, moving with great velocity, have cut in the solid rocks beneath.” Professor Hitchcock, in his geological survey of Massachusetts, discovered “grooves, furrows, and scratches, upon the surface of the rocks, that had never been moved from their place.” The rocks are not only water-worn, and smoothed, but “grooved and furrowed, as if heavy and irregular bodies had been dragged over their surfaces.” The direction of the grooves Professor Hitchcock found uniformly nearly south. They cannot be well mistaken for the natural seams or joints of the ledge, as they generally run in a different direction. Such is their appearance, as to “seem sufficient to lead every reasonable man to the conclusion, that these grooves and furrows were produced by the large bowlders which now strew the surface, and exhibit, in their rounded forms and smooth surfaces, the marks of powerful abrasion.”

The phenomena thus noticed by Sir James Hall, in Scotland, and Dr. Hitchcock, in Massachusetts, were abundantly exhibited in the geological examination of Maine. The furrows were observed in several places, always bearing nearly south. The most incontrovertible evidence of their

origin and cause was discovered in a granite quarry lately opened on the banks of the Sheepscot river, a few miles below Wiscasset. The earth covering the granite ledge had been just removed, leaving the rock newly exposed, having been covered with about four feet of soil, probably ever since the flood. The granite, owing to the large quantity of mica entering into its composition, was more soft than primary rocks usually are. The surface was plainly marked by grooved furrows, running nearly south, and in no way conforming to any natural divisions of the rock. There could be no mistake about it. The appearance was precisely as if immense bowlders of sharp-cornered, hard rock had been powerfully dragged along over the ledge. The scratching of the solid and immovable ledges, and rounding and smoothing of the bowlders, must be owing to the same cause—the rushing over the land of a powerful deluge—sweeping every thing along in its course.

429. *Transporting power of water.*—It may seem, to those who have never particularly examined the matter, impossible for water, moving with any conceivable force, to transport such immense quantities of diluvium, and such huge masses of rock, to so great distances. It is, however, to be recollected, that a rock, though it will not swim in water, yet loses much of its specific gravity, so that it is not much more than half as heavy in water as on land. It is further to be remarked, that, as the flood evidently came from the north, the rocks might, in many instances, be frozen into ice cakes, and borne along, suspended, for hundreds of miles.

But the transporting power of water is much greater than you would imagine. We may judge something of the effects of a powerful deluge by those produced by mountain streams in their overflow. In a plain country, like the valley in which we live, where our rivers flow so gently, we can form little notion of a torrent, or what we call in New

England a freshet. The Wabash and the Ohio sometimes overflow their banks, depositing new layers of alluvial soil, and floating off fences and frail dwellings. But if the Ohio should flow with the rapid current of the Connecticut, or the Saco, or the Kennebec, such a rise of water as occurred a year or two ago, would have swept away every dwelling within its reach, from Pittsburg to Cairo. When the rains fall violently for several days, or the snows of winter suddenly melt in spring, the mountain stream of the north swells beyond its banks, rushes impetuously along its course, and sweeps every thing irresistibly along. Trees, bridges, houses, and huge rocks are swept along as if they were but straws.

Some thirty years ago I was residing on the banks of one of those rapid streams. The source of the river was in a magnificent range of lofty mountains, some thirty miles north of us. Our house stood on a lofty bluff, some half a mile from the river, and the farm, a rich and beautiful interval, stretched along the river shore. The whole country, except the immediate river valley, was mountainous, and rapid streams poured into the river all along its course. One summer evening I retired to sleep amidst a powerful rain. It continued raining incessantly all night. In the morning I looked from my window, and beheld a scene of indescribable ruin. The river, which in its ordinary stages was scarcely fifty feet wide, and so shallow that I have often walked dry-shod across it on the loose rocks of its bottom, now filled all the space from bluff to bluff, and swept along with a fury far exceeding that of the ocean in a storm, and with a thunder scarcely less sublime than that of Niagara.

The next day the river withdrew within its banks, but left exposed a horrid scene of confusion. Our farm was never found again. It lay buried more than ten feet deep beneath a mass of sand, gravel, pebbles, and huge rocks.

Blocks of rock, which a hundred men could not lift nor move from their place, lay scattered all over the field. So enormous was the quantity of diluvial rubbish, and so huge the masses of rock, that no attempt was ever made to reclaim the farm. It yet remains a barren waste.

The farm just below ours was carried off—absolutely abducted. Every foot of soil was swept away, and nothing left but a rocky, pebbly bed, on which the soil had rested.

Another example of the destructive effect of rushing waters, may be seen on the Saco river, a few miles below the Notch of the White Mountains. The river flows along a narrow valley, between lofty mountains. In a beautiful spot, where the receding hills gave space for a larger area, stood, some twenty-five years ago, surrounded by cultivated fields, a neat cottage, the home of a father and mother with nine children. During a powerful rain one summer night, the river suddenly rose from its rocky bed, and overflowed the valley. At the same time an immense avalanche of earth became loosed from its moorings on the mountain summit and side, and slid down, increasing in width and depth as it proceeded. Rushing down impetuously, it swept along trees, huge rocks, and every thing it met. Roused from their sleep by the noise, the family, as is supposed, arose and fled; but the avalanche overtook them in the darkness and buried them, father, mother, children, and all, in one mass of ruins. On it swept toward the river, rushed evidently across its bed, and effectually dammed it up. The waters, being arrested, accumulated till they burst through the temporary barrier of the avalanche, and rushed into the valley below, distributing in their mad career such a quantity of diluvium, and such huge masses of rock, as to astonish the observer, by the overwhelming evidence of the inconceivable power of rushing waters. Ten years after the catastrophe I passed up the valley. The house was standing yet, for it strangely escaped the

avalanche; and the family, had they remained quiet, might have been saved unhurt. When I was there the house yet stood tenantless, save by a poor little mouse, which my presence scared from one of the deserted rooms. The halls, which had rung with the merry laugh of childhood, were voiceless, and all around was a scene of desolation—trees upturned, and rocks piled on rocks in undistinguishable confusion. The entire valley, for miles below, exhibited the omnipotent effects of the deluge of waters, that swept down after the accumulated mass burst the temporary barrier.

I venture to affirm, that one who has ever seen the marks left by this overflow of the Saco, or by that of the Sandy river, when some farms were swept away and others buried, will find no difficulty in believing all the diluvium and bowlders discovered in Europe and America are the results, effects, and evidences of a mighty flood—a universal deluge.

Mr. Lyell, in the first volume of his geology, gives an account of a catastrophe, similar to that of the Saco, happening in one of the valleys of the Rhone. Avalanches of snow and ice being precipitated into the bed of one of the streams flowing into the Rhone, near Bagnes, formed a dam, which caused an accumulation of the waters above. When in summer the snow and ice melted, the lake suddenly burst the barrier, and swept with awful destruction over the valleys and plains below. So great was the power of the water as to move, for a quarter of a mile, a rock which proved, from actual measurement, sixty paces in circumference.

430. *Transported diluvium not the result of causes now in operation.*—Mr. Lyell and some others labor to show, that all the diluvium and bowlders, discovered on the surface of the earth, may be merely the effects of just such temporary river floods as we have described, and of other

causes now in operation. If diluvium and bowlders were found only along the river valleys, we might, perhaps, account for the phenomena without supposing a universal deluge. But, surely, no river could ever lodge bowlders on the summit of Mount Katahdin, more than five thousand feet high. Did Mr. Lyell ever travel over the elevated ridges and lofty mountain ranges of Maine? He would find these diluvium and bowlders in positions where no river could possibly leave them. A river flowing from the northern boundary of Maine to the Atlantic, three hundred miles wide, and five thousand feet deep, would be a strange phenomenon. It surely would pass with common people for a flood—as respectable a one as the narrative of Moses requires.

Mr. Lyell's geology is exceedingly interesting and valuable for the facts he has accumulated. But his theories are unsatisfactory. I never could see how his theories could appear, to his own mind, consistent with his array of facts.

431. *Physical cause of the deluge.*—Though the deluge was made, in the providence of God, to subserve a great purpose of penal administration in the government of the race of man, yet it may be allowed us to inquire for its physical cause. Many years before the deluge, God said to Noah, "Behold I, even I, do bring a flood of waters upon the earth." Again, after the ark was finished, God directed Noah to enter into it with all his house, "for yet seven days, and I will cause it to rain upon the earth forty days and forty nights, and every living substance that I have made will I destroy from off the face of the earth." After Noah and his family, and the animals he was directed to protect, were safe in the ark, "all the fountains of the great deep were broken up, and the windows of heaven were opened, and the rain was on the earth." The deluge was, therefore, an act of God. But it was no less his act if brought about in accordance with the laws of nature,

than if in opposition to those laws. God may work by physical causes or without them. When he intends merely to accomplish a work, he usually operates by physical causes. When he intends, not only to accomplish the work, but to give man an exhibition of his almighty power over nature, he usually operates by miracle. The deluge appears partly natural and partly miraculous. The rush of waters over the dry land was undoubtedly effected through physical causes, under the special direction of omniscient Wisdom, and by the exertion of almighty power. The bringing of the flood at that particular time, a time marked by prophetic word, and for the particular purposes of penal judgment, might be the result of miraculous interposition.

The flood would appear the more miraculous in the eyes of the men of that age, inasmuch as they knew nothing of rain. We are told that in those early times, and in that part of the world, it did not rain. The earth was watered by a mist or dew. The fact that the rainbow had not appeared before the flood, is satisfactory evidence that showers of rain, such as frequently occur in most parts of the world, were totally unknown to the men of that age.

There are several physical causes which might produce a flood of water over all the dry land, so as to cover the highest mountains on the globe. A change of direction of the axis of the earth would produce that result. Should now the poles and the equator change places, the earth moving on an axis running from east to west instead of north and south, the waters of the sea would, by the change in the direction of centrifugal motion, be thrown over the land, submerging the present continents, and laying bare many parts of the ocean bed. If, therefore, the axis of the earth once coincided with the plane of the equator, and the equator, as a matter of course, lay in the plane in which the axis now is, and the change of axis was made, producing the flood, then the portion of the globe which was dry

land before the flood, must now be covered by the sea, and the dry land that now is must have been drained from the ocean bed at that time. A change of climate would also result. The regions equatorial before the flood would become polar, and the ice and snow of the frigid zones would become exposed to the melting sun of the tropics. Appearances are very much against this theory. There is satisfactory evidence that the relative positions of the sea and land, the mountains, valleys, and great rivers, have not materially changed since the creation of man. Mathematicians have also proved, by a process of reasoning altogether too abstruse for a popular lecture, that the axis of the globe cannot have changed since its first revolution.

We think the physical cause assigned for the deluge by De La Beche, the most plausible we have seen. De La Beche makes no attempt to identify the deluge, which most incontestibly has passed over the globe since the present order of things, with the deluge of Noah. Indeed, he seems studiously to avoid all notice of the Scriptures. So far as I now recollect, you would not, from reading his geological manual of more than five hundred pages, suspect he ever heard of the Bible. He infers, from the phenomena of diluvium and bowlders in Europe and America, that there occurred, at the time of the flood, an elevation of land, by the agency of heat in the interior parts of the earth, under the polar seas, driving the ocean southward over the continents, with a force proportioned to the intensity of its action.

This, to speak in human language, would be a physical cause the most manageable possible. Had you or I power over the internal heat of the earth, such as the skillful engineer has over the steam-engine—power to raise it to any desirable degree, and hold it there, and perfectly control its action—we might produce a flood of any extent, force, and duration. A sudden and great elevation of land

under the ocean would produce a sudden, and violent, and overpowering rush of the waters over the dry land. A gradual and long-continued action would produce a long-continued flood. The interior of the earth is a great steam-engine, constructed by almighty Power, and managed and controlled by omniscient Wisdom. At his command it might direct its energies to the land under the Arctic Ocean. By action rightly timed, properly directed, and suitably modified, it might so upheave the ocean bed as to produce just so much, and so long-continued a deluge, as God might please "to bring on the earth." Is not this what is meant by the "fountains of the great deep being broken up?" The inspired historian also says the "windows of heaven were opened, and the rains fell." That was a necessary result of the "breaking up of the fountains of the great deep." Atmospheric disturbances, rains, and thunder and lightning, usually accompany or follow earthquakes, or other revolutions and disturbances of the interior of the earth.

I do not say that it was necessary for the Almighty to use any physical cause, or to work by any physical law, in bringing a flood on the earth; but I do say, that such a cause as we have supposed—the upheaving of the bed of the polar seas—would produce precisely such effects as the flood has marked on the surface of the earth. The elevation thus produced might remain covered with shallow water, or a great plain of dry land, or some great mountain-land, in the unexplored, and unexplorable regions about the north pole.

432. *Conclusion from the diluvial argument.*—From incontestible facts we therefore conclude,

(1.) That the face of the earth has been swept by a deluge. In its progress it has left its unmistakable marks, by grooves and furrows in the solid rock, and erected its imperishable monuments, by immense heaps and huge

blocks of rock, in positions where they never could have been deposited by any other known means. In addition to the common transport of bowlders described in this lecture, we should notice immense blocks of rock, piled on other rock, forming the famous rocking stones. These stones, some of them weighing forty or fifty tons, are frequently so poised on other rocks, that a single hand can move them, though a thousand men might find difficulty in throwing them down. They could only be so elevated and deposited by water, or more probably ice, which, bearing up the rock, drifted against some solid mass, was arrested with its rocky burden, and finally melted away, leaving the rock poised in air. Often we find bowlder rocks on mountain summits, evidently coming from lower ledges in the valleys, and being driven up the mountain side by rushing water or floating in ice. The general contour of many of the hills, and the shape of the valleys, in particular regions, are such as would arise from the action of a deluge.

(2.) The deluge was recent. We speak geologically. Whatever has occurred since the creation of man, we call in geology a recent event. The effects which we have described of the deluge are surface effects. The hills, valleys, and rivers, as well as all the regular strata of the globe, were then much as they are now.

(3.) The deluge was general. Its effects are seen wherever scientific eye has been directed.

(4.) The general direction of the waters over the entire globe was from north to south, varying only to conform to circumstances of valleys and mountain ranges.

(5.) It was sufficient to produce all the destructive effects on animal life affirmed by the sacred historian; for it is proved to have covered the highest mountains yet examined, and its continuance must have been sufficiently long to "destroy all flesh wherein was the breath of life from under heaven."

(6.) On the whole, there appears the strongest possible presumption, that the last deluge of geology, and the deluge of sacred history, were one and the same event.

I must say in candor, that, on my own mind, this kind of evidence of the truth of revelation is of the highest possible authority. Moses knew nothing at all about geology. He did not know, probably, one rock from another, and had never, unless he were in science and philosophy one hundred generations in advance of his age, had the remotest notion of diluvium or bowlders; and yet, hundreds of years before the first record of historic event was made in the annals of any other nation than the Jews, he records the particulars of a great cataclysm, whose vestiges are traced, by imperishable marks on the earth itself, more than four thousand years after the event occurred. Surely the record of the Bible is the record of Inspiration.

LECTURE XIX.

THE UNITY OF THE HUMAN RACE.

Importance of the question—The question stated—Species defined—Color not a characteristic of species—Influence of climate on color—Shape of features and of skull not a characteristic of species—Origin and transmission of peculiarities—Varieties more likely to spring up and be perpetuated in ancient than in modern times—Black skins and negro features not always associated—External modifications innumerable—Each species of animal characterized by uniform anatomical structure—Specific characteristics in the development of instinct and of mind—Power of self-perpetuation a characteristic of species—Language of mankind—Comparison of languages—Oneness of the moral principle in man.

433. *Importance of the question.*—No question of fact, in the whole range of divine revelation, is of more importance than the one on whose discussion we now enter. It is certainly the teaching of the Mosaic narrative, and no fair and reasonable interpretation can evade it, that God created, at the time of setting in order the present system of things, one single pair of human beings, and that from them have sprung all the families of the earth. The apostle of the New Testament says expressly that God "hath made of one blood all nations of men to dwell on all the face of the earth." This passage unequivocally teaches the unity of the human race.

The language of the historians, of the prophets, of the poets, of Christ, and of the apostles, all conforms to the same theory. And this is not all. The whole scope and tenor of the Bible run in harmony with this fundamental and fixed idea.

If all men are not descended from one common stock—one single pair—if there have been separate and independent creations of humanity, then the prominent doctrine of original sin, the Gospel plan of human salvation, the deep mystery of the atonement, and the resurrection of the

body, are all blotted from religion's book. The commission of Christ to his apostles, "Go into all the world and preach the Gospel to every creature," would be a nullity, and all the hope of the Christian in the Savior of the world would be a mockery. The fact cannot, and should not be concealed from you, that the doctrine of the unity of the human race has been repeatedly and plausibly attacked. Many men, of considerable pretensions to science, have maintained, that it is impossible to reduce the many varieties of humanity to one species; that there are such strongly-marked characteristics of division between different nations as to preclude all supposition that they could have sprung from a common progenitor; and that no conceivable causes could have altered the European's color and shape into the negro's, or changed the skin of the Ethiopian to that of the Asiatic. Some French writers have discovered, as they thought, some fifteen distinct races of men, and supposed there were as many, if not more, distinct, separate, and independent creations. And while I am writing, a leading magazine of the United States, just laid on my table, announces a new work in this country, maintaining, with "much skill and precision," that the Scripture doctrine of the unity of the race cannot be true.

In approaching this subject I regret the want of some valuable authorities on the question. There are some extensive collections of facts, which I have never seen, nor can I obtain the books in my present location. This I regret. The more facts on the subject the better. I must avail myself of what materials I have, and present you the phase of the subject, as it appears to me, trusting I may arm you with a slight defense against the insidious attacks of infidelity.

434. *The question stated.*—We shall endeavor in this lecture to present some facts from physical and moral science, confirming the Bible doctrine of the unity of the

human race. In order that we may be able to treat the subject with the more precision, we will put the question in the form usually adopted in discussing scientific theorems.

All the varieties and individuals of the human race belong to one and the same species.

435. *Species defined.*—As we have adopted the scientific term species, and as it will occupy an important part in our investigation, we may find it necessary precisely to define it.

Cuvier's definition of species is as follows: "*A species includes the individuals which descend from one another, or from common parents.*" Those races more or less different, which may yet have descended from one common origin, he calls "*varieties of a species.*"

Linnaeus considers *species* as including "*all the individuals propagated from one stock, and having in common certain distinguishing characteristics, which will never vary, and which have remained the same since the creation of each species.*"

I hardly need inform the reader that the names of Cuvier and of Linnaeus stand at the head of their respective departments of natural history—the one being the highest authority in comparative anatomy and the history of the animal kingdom, and the other in botany. They agree, in all essential particulars, in their definition.

The theory of species, as thus defined, supposes that, at the time of the creation, God made, male and female, one stock or pair of each kind of animal and of vegetable; that each species thus created had certain characteristics, distinguishing it from every other species, and which, amid all the varieties springing up among each species, have never varied; and that, within the limits of these essential characteristics, numerous varieties may spring up.

436. *Color not a characteristic of species.*—It is important to distinguish between the essential characteristics of species and those accidental properties which give rise to vari-

eties. In no department of the vegetable or animal kingdom is color a characteristic of species. You have only to look among the herbs of the field and the flowers of the garden, to find innumerable varieties and shades of color among plants indisputably belonging to the same species. Among animals the varieties are still greater. These varieties are even more numerous and marked among domestic than among wild plants and animals. Wherever man's influence extends, there are seen cross breeds and varieties. In the animals which are the universal companions of man, in every climate, the varieties appear the most numerous and striking. The dog, the cat, the common hen, the ox, and the horse are found of every possible color, and some of them of every variety, shade, and combination of color; and yet no man of science doubts that all the dogs, and all the cats, and all the oxen, and all the horses, and all the hens, in the world, belong each respectively to one and the same species of dog, cat, ox, horse, and hen.

Both the color and the texture of the hair of animals undergo frequent changes. Every attempt to produce wool in the West Indies fails. Sheep, transported to hot climates, lose their wool, and become hairy. In Angora almost every animal—sheep, goats, rabbits, and cats—is covered with a beautiful, long, silken hair, so celebrated in oriental manufactures. Bishop Heber informs us that dogs and horses, carried into the hills from India, are soon covered with wool, like the shawl goats of that climate.

Varieties of color in the complexion of men are evidently to be referred to the same causes as in the hair of animals. There is a well-known relation, in men, between the color of the skin and of the hair. A negro skin is associated with black, woolly hair; a copper-colored skin with black, straight hair; and a fair skin with light hair.

We have seen (§202) that, in man, the color of the skin depends on the secretion and deposition, in the middle coat

of the skin, of a pigment, which is black in the negro, more or less white, though exceedingly various, in the European, and a chalk white in the albinos.

437. *Influence of climate on color.*—Some men of distinguished claims to science, have supposed all the varieties in color among men owing to difference in climate. We do not think the evidence, however, sufficient to authorize us to conclude that climate alone is sufficient to account for the difference between the negro and the Caucasian; but that much, very much change of complexion may be effected, in a series of generations, by climate, there is no doubt. Bishop Heber says that the Persians, Greeks, Tartars, Turks, and Arabs, of India, in a few generations, even without any intermarriage with the Hindoos, assume the deep olive tint, little less dark than the negro, which seems natural to the climate. The Portuguese nations form unions among themselves alone or with other Europeans; yet the Portuguese have, during a residence of three hundred years in India, become as black as Caffres.

On the other hand, the negroes of North America have not yet quite whitened out by living in a cold climate. It has, however, been always observed that black color prevails in the torrid and lighter in the temperate zones.

Supposing white, in some of its varieties, the original color of man, if we knew at what time the negro complexion became marked and fixed, we could form some estimate of the share which climate has had in effecting the change; but the oldest record—the Bible—is not explicit on color. The people of the interior of Africa are called, in the Hebrew Scriptures, Cushites, and, in the Greek translation, Ethiopians, both which terms signify people of sunburnt faces. It is evident, however, that the negro faces were fixed as early as the days of Herodotus, who lived nineteen hundred years after Noah, and even as early as the time of Homer, who lived four centuries before Herodotus. My

own opinion candidly is, that, while color may be materially modified by climate and other circumstances, the distinctive and well-marked negro complexion was originally an accidental variety, which has been transmitted and perpetuated. There may have been some Providential design in the accident. It is a conceded matter of fact, that black is better adapted than white to hot climates; and the black variety may have been produced by some mysterious and latent law of nature, under the direction of an all-wise Providence, for the more universal diffusion of humanity. Is it not as reasonable to suppose that God might modify the color, as confound the language of the human race?

Waiving, however, the question of design, we are inclined to consider the strongly-marked black variety as originating in the same manner as the strongly-white—the albino color. It is conceded that the albino is the result of disease. The vessels of the skin, which ought, by nature, to secrete a black pigment, through disease secrete a substance in which color is totally wanting. These albino varieties are found both in Africa and in Europe. The children usually inherit the peculiarity from the parents; and, had the first albino been isolated from a miscellaneous community, with only one “helpmeet for him,” as might be the case with the negro, in the early history of the race, we might have had now, in the same parts of the world, a race of albinos, as distinct and separate as the race of negroes.

438. *Shape of varieties and skull not a characteristic of species.*—Features and shape of the head have long and generally been observed to vary among the varieties of men. The rounded head and aquiline nose of the European, the square head and high cheek-bones of the Asiatic, and the low forehead, flat nose, and thick lips of the African, are well-known peculiarities of each variety.

Thomas Pownall, Governor of Massachusetts about the middle of the eighteenth century, first suggested the propri-

ety of attending, in addition to color, to the form of the skull in the various families of mankind. Camper, a German physician and naturalist, who lived during the latter part of the last century, devised a rule, by which the heads of different nations might be mutually compared, so as to give definite results. The rule was founded on the measurement of the facial angle. This angle is measured by drawing a line from the prominent centre of the forehead to the most advanced part of the lower jaw-bone, and observing the angle which it makes with the horizontal line. Camper found the facial angle of one variety of ape 42° , of another 50° , of the negro 70° , and of the European 80° .

Blumenbach greatly modified and improved the system of Camper, taking into account the breadth as well as height of the skull. He takes the European form for the original type, the skull being symmetrical, and the cheek and jaw bones concealed by the greater prominence of the forehead. From this type the negro and the Asiatic depart in opposite directions—the one by its greater length and narrowness, and the other by its excessive breadth. The Polynesian skull is a variety intermediate between the negro and the European; while the American Indian is a variety between the Asiatic and European.

These differences are all acknowledged, but yet they do not prove that every difference found in the skull marks a distinct species.

(1.) Equal differences are found in animals of the same species. The skull of the mastiff and of the Italian grayhound differ from one another far more than do those of the European and the negro; and yet every criterion which can be given of species will comprehend the two extremes between which a train of intermediate gradations can be established. The skull of the wild boar, Blumenbach observes, does not differ less from that of the tame swine—its undoubted descendant—than those of any two human

racés from one another; nor is the difference less striking among the varieties in every species of domestic animal.

(2.) The facial angle not only varies among the different races of men, but among minor varieties and individuals of the same race; so that, if it form the characteristic of a species, we must make the number of species incalculable. You have only to look about you, on the profile of any number of persons you meet, to perceive that facial angles greatly vary; and yet you would not suspect two of your neighbors to belong to different species of men, created at different times. I have before me no table of comparative measurements of crania, except one in Squier and Davis' *Ancient Monuments of the Mississippi Valley*, giving the results of the measurement of twelve skulls from the mounds of the Mississippi valley, and of three from Peru. Those of the Mississippi region vary in measurement nearly 20° , running through nine intermediate steps, as follows: $61^{\circ} 51'$, 70° , 72° , 76° , 77° , 78° , 79° , 80° , and 81° . Those from Peru are 71° , 72° , and 74° . Would any one pretend that so many different species or creations of man occupied, in ancient times, the American continent?

If we take into account the breadth as well as height of the skull, and measure its internal capacity, the scale, according to Dr. Morton, is as follows: the Caucasian head contains eighty-seven cubic inches; the Asiatic, eighty-three; the American, eighty-two; the Polynesian, eighty-one; and the negro, seventy-eight. The variation, therefore, between the mean capacity of the negro and the European skull is only nine inches. But in a table of Dr. Morton, made from comparing about three hundred skulls of the ancient and modern Indians, the variation is no less than seventeen inches, the smallest—the Peruvian—being seventy-three, and the highest—one of the mound builders—ninety inches.

Thus we see, between different tribes of the American Indians, much greater differences of facial angle and of

internal capacity of the skull than between the negro and the European.

We think it is, therefore, settled, that neither shape nor internal capacity of the head can form a distinctive characteristic of species.

The shape of the face and of the nose, and thickness of the lip, are even less important, as characteristics of species, than the form of the skull. Animals, unquestionably of the same species, differ, in their general features, far more from each other than do the different varieties of men. What a contrast there is, says Wiseman, between the slow, massive, long-horned ox, that traverses the streets of Rome, and the small-headed, clean-limbed animal, which an English farmer most prizes! and what differences of countenance may be observed among the varieties of dog! Buckingham, in his travels in the east, speaks of extraordinary modifications in the camel. "In some of the caravans which we passed," says he, "there were camels of a much larger kind than I had ever seen before, and as different in their forms and proportions from the camel of Arabia, as the mastiff is from the grayhound. These camels had large heads and thick necks, from the under edge of which hung a long, shaggy, dark-brown hair. Their legs were short, their joints thick, and their carcasses round and fleshy, though they stood at least a foot higher from the ground than the common camels of the Arabian desert." I need but allude to the influence of education and refinement on the cast of the features and the general appearance of the countenance. You may take a rude, ragged boy from the woods, and dress him up and educate him, and his features will undergo such a metamorphosis, that his mother would hardly recognize him. How much the ages of mental degradation, to which the negroes have been subject, has had to do with their personal appearance, it is impossible to estimate; and personal appearance founded on mental character and social

condition is transmittible, as well as that founded on any merely physical peculiarity.

439. *Origin and transmission of peculiarities.*—Our theory supposes each and all the varieties in color, form, shape, and general appearance, among the different nations of men, as well as among individuals of the same nation, may have originated in some accident, and been transmitted by the ordinary laws of nature. Natural history is not wanting in examples, both among men and animals, of the production and transmission of accidental varieties of the same species. Dr. Prichard gives an example of a breed of sheep reared, within a few years, in England, and known by the name of the otter breed. It sprung up from an accidental variety, or rather deformity, in one animal, which communicated its peculiarities so completely to its progeny, that the breed is completely established, and promises to be perpetuated. It is valuable on account of the shortness of its legs, which does not allow it easily to get through fences. Dr. Wiseman gives an account of an English family, traced through three generations, called the Porcupine family. The founder of the family was first exhibited, as a boy, by his father, in 1731. The boy was described, in the philosophical transactions of that year, as having his body covered with warts, as thick as pack thread, and half an inch long. They were said, by the father, to have appeared first on the child at the age of nine weeks. At the age of forty years the same individual was exhibited again, and described by Mr. Baker. He had been the father of six children, every one of whom, at the same period—nine weeks after birth—had presented the same porcupine peculiarity. The only surviving child, then eight years old, was exhibited with the father. In 1802 the children of this boy were exhibited, and fully described by Dr. Tilesius. The grandfather, father, and grandchildren had the same peculiarity. The whole body, except the palms of the hands, soles of the

feet, and the face, was covered with a series of horny excrescences, of a reddish-brown color, hard, elastic, and about half an inch long. Mr. Baker, from seeing only the first specimen of the family, remarks: "It appears, therefore, past all doubt, that a race of people may be propagated by this man, having such rugged coats, or coverings, as himself; and if this should happen, and the accidental origin be forgotten, they might be deemed a different species of mankind." It seems that what Mr. Baker thought probable did really happen. The man did propagate a race like himself, extending through two generations. Whether the peculiarity is still transmitted, or become obsolete by the extinction of the family, I know not.

Another more common variety, running through whole families, is marked by six fingers. In ancient Rome it was designated by a peculiar name—the *Sexdigiti*. The peculiarity has been traced, both in England and in Germany, through four generations.

We may be asked, if varieties in color and shape of features, such as distinguish the negro from the European, may have arisen from accident, and been transmitted to posterity, in the same manner as the peculiarities of the porcupine and six-fingered families, why do not such accidents happen in modern times? Well, perhaps they occasionally may. In the best-regulated families some striking peculiarity does often distinguish one child from the rest of the family. Buckingham says he found an Arab family beyond the Jordan, remarkable for having, with the exception of the father only, negro features, a deep-black color, and woolly hair. He thought they must have been born of an African mother, but was assured that both the males and females of the present and former generations were all pure Arabs, of unmixed blood, both by descent and marriage, and that a negress had never been known in the history of the family.

440. *Varieties more likely to spring up and be perpetuated in ancient than in modern times.*—But this question of the accidental origin and subsequent transmission of varieties may deserve from us more attention. Were it true that no varieties appeared in our times, or that, if they appeared, none were transmissible, still we might, from analogy, conclude such things might happen in the early history of the human race. We have seen, in our epitome of geology, that nature has not always moved with the slow and gradual pace which now marks her progress. Time was when volcanoes were bursting out from every hill-top, and covering with burning lava all the plain; when mighty deluges were sweeping over the earth; when the soil produced gigantic ferns fifty feet high, and accumulated in the valleys material for coal to serve the purposes of man for untold ages; and when monstrous saurians paddled in the marshes, and overgrown mammoths browsed on the hills.

In the early history of the human race, the developments of mind were altogether more marked and striking than in modern days. "Assuredly," says Wiseman, "there was a vigor in the human mind, as compared with ours, gigantic, when the Homeric songs were the poetry of the wandering minstrels, when shepherd-chiefs, like Abraham, could travel from nation to nation, and even associate with kings, and when an infant people could imagine and execute monuments like the Egyptian pyramids."

And where, in the whole history of literature, will you find such exquisite poetry, as in the terrible denunciations of the Hebrew prophets, or the passionate lament of the Hebrew bard over his royal friends fallen on the plains of Gilboa?

Physical as well as mental peculiarities were then more strongly marked, and easily perpetuated, than now. Each child of a family became the founder of a new tribe. The

sons of Noah went each his way. The children of Isaac, by the same mother, became the founders of distinct and rival people. In such an age, and under such circumstances, such casual variety might spring up among the children of a family, and the peculiarity, whether of color or feature, might, under the influence of favorable circumstances, such as the isolation and subsequent intermarriages of the family in which it began, become fixed and indelible in succeeding generations. As we have before remarked, there might be Providential design in suffering casual impressions to become permanent and indelibly stamped, that thereby all parts of the earth might be the more readily inhabited. We need not suppose that the black color of the negro is owing to the mark set on Cain, or to the curse on Canaan, for we should still have to account for the color of the Polynesian and the American Indian. It is much more simple, as Wiseman remarks, to allow that one individual or one family, placed in peculiar circumstances, may have given rise to peculiarities, which, in consequence of intermarriages and the continued operation of the same causes, may have become fixed and enduring.

441. *Black skins and negro features not always associated.*—We have seen that both color and features are usually taken into account, in determining the races or varieties of men. But naturalists are often embarrassed in classifying, on this principle, the inhabitants of some particular localities. There are, in the very central parts of Africa, many nations, who are glossy black, without a sign of negro features. Mungo Park describes the Foulahs as having small features and soft, silky hair, without either the thick lips or crisped wool, which are common to the other tribes. A late traveler describes the inhabitants of Timbuctoo, as being of a fine, deep-black color, with aquiline noses, thin lips, and dark eyes. Burckhardt describes the inhabitants of Nigritia as perfectly black, with the lips of the negro,

but not the negro nose or cheek-bones. The natives of Abyssinia are perfectly black; yet, in language, features, and form of the skull, they are perfectly European. Burckhardt mentions the inhabitants of Sonakin, on the African coast of the Red Sea, as being of the darkest brown, approaching black, yet with nothing of the negro character or countenance, but with the same features, language, and dress as the Arabs.

442. *External modifications innumerable.*—We see, therefore, that it is vain to look for characteristics of species in color, or any modification of external appearance. Should we distinguish species by any such accidental mark, we should have to suppose hundreds of separate and independent creations of humanity. Even in the family to which we belong—the European, or, as it is generally called, the Caucasian—there is a series of modifications giving rise to varieties, which, if not so strongly marked as the European and the negro, are equally as indelible. The Germans, the Greeks, the Hebrews, and the English, may easily be distinguished by national characteristics; yet no one would maintain that they sprung each from an independent stock. There are found families having some characteristic feature, which is never obliterated; yet such feature is never to be deemed a mark of independent origin. We must look for other and less various and changeable characteristics of species.

443. *Each species characterized by uniform anatomical structure.*—However much the varieties of the same species of animal may vary in color, size, and general outward appearance, yet the number, structure, articulations, and relations of the bones remain the same; nor can any influences, natural or human, change or modify them.

Cuvier, whose authority in all matters of comparative anatomy is certainly first among all men, ancient or modern, says, in his discourse on the revolutions of the surface of

the globe, that he has compared the skeleton of the fox of the extreme north and of Egypt with that of France, and found only individual differences; that the wolf of the torrid and of the icy zone differ only in hair; that elephants grow larger in one forest than in another, and have larger tusks where the nourishment is more congenial to the formation of ivory, but that in any part of the most dissimilar individuals there cannot be discovered the least difference in the articulation of the bones; that, notwithstanding all varieties of color and appearance, the skeleton of an Angora cat has no decided or perpetual difference from that of a wildcat; that a greater or less height, horns longer or shorter, or wholly wanting, a lump of fat more or less developed on the shoulders, form the only difference in oxen, their internal skeletons being precisely the same. The greatest varieties, Cuvier remarks, are found in the dog. They vary in color, in the thickness of the hair, in size more than a hundred-fold, in the form of the ears, and nose, and tail, and in the shape of the head; but the relations of the bones remain the same, and the shape of the teeth never undergoes any palpable change.

Some breeds of dog have an additional toe on the hind leg, as some families of men have a supernumerary finger on the hand; and this he pronounces the maximum difference ever discovered among the individuals of any species in the animal kingdom.

Now, though not much of a comparative anatomist, I undertake to say, that no two species of animal have precisely the same number, relations, and articulations of the bones. A good anatomist, like Cuvier, could distinguish any number of species from each other by the skeleton alone.

Again, I venture to ask, did you ever hear that any anatomist could discover any difference in the number, arrangement, and articulation of the bones of the skeleton

of the most dissimilar varieties of men? I have never dissected any human being, nor do I intend ever to do it; but I would like to know what material differences, sufficient to form the characteristic of species, any anatomist has found between the skeletons of the European, the Asiatic, and the African. I have never seen this argument presented, nor this issue made, by any writer on the physical history of man; but, unless I am greatly mistaken in facts, the argument for the unity of the race, drawn from anatomy, is unanswerable.

444. *Specific characteristics in the development of instinct and mind.*—"We must suppose," says Mr. Lyell, "that when the Author of nature creates a plant or animal, all the possible circumstances in which its descendants are destined to live are foreseen, and that an organization is conferred upon it which will enable the species to perpetuate itself, and to survive under all the varying circumstances to which it must be inevitably exposed." This remark is true of the instinctive and mental, as well as of the physical organization of animals. Each species of animal is endowed with all the instincts that can ever be necessary to its preservation in all the possible and variant circumstances in which it was designed by the Creator to be placed. The limits of these instincts mark the limits of the species.

In many species of animal some instinctive peculiarities may lie dormant for successive generations, because the circumstances calculated to call them forth have never occurred. The red-headed woodpecker of our climate builds its nest in a hole dug out in a standing dead tree; but the same species, in the more southern latitudes, are said to suspend their nest to the slender limb of a tree, to avoid depredations from the snakes. Now, in the Indiana woodpecker this peculiarity of instinct may still lie dormant, and might be developed by circumstances. The Rocky Mountain sheep, in the retired parts of the mountains, where

hunters seldom penetrate, are said to exhibit remarkable simplicity of character, and suffer themselves to be approached by man. But let them be often hunted, and the latent instinct, given them for protection, but remaining dormant for ages, is suddenly developed, and in obedience to it, on the first appearance of danger they flee away to inaccessible heights.

Whatever differences of instinct the same species may manifest in different circumstances, yet, in the same circumstances, the same species invariably exhibit the same instincts. No species has ever acquired any new faculty of instinct or mind. Each had in the beginning of its creation all it has now. All modifications, therefore, consist, not in the acquisition of new properties or faculties, nor in the loss of old ones, but in the development of latent and dormant powers, or in the suspension and cessation of those before exercised.

Wild animals when domesticated undergo great changes. Many instinctive properties exhibited in their wild state disappear, and many new traits of character are assumed. The change, however, consists only in developing dormant instincts, and in ceasing to use artifices necessary only in a wild state. The wild elephant caught in the woods of India becomes, in a few years, by the development of latent instincts, perfectly domesticated; while the zebra, being not endowed with such instincts, though he may be tamed, can never be domesticated.

All varieties of the dog, however dissimilar in appearance and wild in habit, may become domesticated. But, though we have seen foxes tamed, yet no one ever heard of a race of domestic foxes. The property of domesticity forms, therefore, one of the specific instinctive differences between the dog and the fox. We have another striking example in the common hen, and its nearest relative, the New England partridge. The partridge of the north is about

the size of the hen, and greatly resembles it in external appearance. But the partridge cannot be domesticated. Place its eggs under the hen, and let them be hatched, and as soon as the imprisoned young are fairly out of the shell, they will put out for the woods; nor can you coax them to stop long enough to eat with you, or to exchange the formalities of parting. Here we see a specific instinctive difference between the hen and the partridge.

The domestication of the sheep, ox, horse, hog, cat, and dog, are therefore owing to the existence in each species of peculiar instincts, adapting them to domestic circumstances. While the species remains wild, these peculiar instincts are either latent or exhibited under other modifications. Subject the species to a domestic state, and many of the modifications of instinct in its wild state, being no longer necessary, are laid aside, while new developments of powers formerly dormant are called forth by new circumstances.

There seems in each species of animal a limit to instinctive and mental development, beyond which it never advances. Between the lowest and the highest extreme of intelligence, varieties of the species and individuals of the varieties may exhibit great variations. But the limit of the development in each species forms one of the characteristics, which have remained fixed since the creation, and will for ever remain fixed. It may not be always easy for us to determine the limit of this development. We may more easily point out the specific difference in the disposition of the leopard and the kid, the lion and the lamb, the bear and the ox, than the limit of intelligence, beyond which each may never go. Yet that each species has its limit, and that all efforts by training and education to urge the species beyond that limit would be hopeless, there can be no doubt. I think the cat could never be taught to watch like the dog. The pig may, it is said, be highly educated—even learned to dance and to spell—but I strongly suspect he would be a

pig still, and never could become so accomplished a gentleman as the rooster.

It is probable that all our domestic species of animals have long since reached their utmost limit in the development of instinct and intelligence. The ox, the sheep, the horse, the dog, the cat, will probably never hereafter exhibit, as a species, any new manifestation of instinct and intelligence. Even the "half-reasoning" elephant seems incapable of any further development of intelligence. He reached his limit centuries ago, nor will he ever pass it.

Among the varieties of men there are conceded to be great diversities of intelligence. So there are among individuals of the same nation, and even the same family. But has any philosopher yet pointed out specific differences of mind among men? Do we need one system of mental philosophy for the Indians, another for the negroes, another for the Europeans, another for the Asiatics, and another for the Polynesians? Do not all nations, all varieties of men, equally receive their ideas originally by sensation, and modify them by reflection? Are not all men originally subject to the same mental emotions? Are not all governed by the same laws of belief, of association, and of reasoning? I am, as you know, no great metaphysician. Indeed, I make little or no pretensions to mental philosophy. But while I have been accustomed to explain the habits of cats, dogs, horses, and oxen, by laws of instinct specifically differing, I have never even thought of applying one principle of mental philosophy to a negro, and another to an Indian, nor have I ever heard of a man who had thought of such a thing. If it be true, that men specifically differ in their mental phenomena, there is a chance for some one to distinguish himself by new systems of Asiatic, and Indian; and African mental philosophy. Here is opened a new field for scientific enterprise and research, a field that Aristotle, and Bacon, and Locke, and Stewart, and Reid, and Brown,

never saw, nor heard of, nor imagined. It must be altogether a new idea, of which these great men never conceived.

445. *Power of self-perpetuation a characteristic of species.*—We now approach a universal, unfailing, and unmistakable character of species. Nature has furnished, to distinguish one species from another resembling it, and to determinate different species from mere varieties of the same species, a rule, which, when accurately applied, can never fail. The application of this test must, it seems to me, for ever settle the question of the unity of the human race. As we are dealing in matters of fact, it is proper I should fortify the principles I advance, and the facts I assert, by unquestioned authorities. Cuvier, the acknowledged prince of zoologists throughout the world, thus lays down the principle, or the rule, founded on observations in natural history, which for extent and accuracy have never been exceeded, and probably will not be for the next thousand years: "Whenever the promiscuous intercourse among the varieties of any animal produces individuals capable of propagation, it demonstrates the unity of the species."

The late Dr. Godman, our own Cuvier, thus speaks of the principle: "Wherever we find one race of animals capable of having its peculiarities entirely obliterated by intermixture with another, and the altered offspring as prolific as the parent stock, we may feel certain that such races, however they may be arranged in an arbitrary nomenclature catalogue, are but varieties of a natural family. There is a law of nature, shown, by the prolonged experience of ages, to be invariable, that although two species of the same genus may produce offspring partaking in a great degree of the qualities of both parents, yet that offspring is sterile, and unproductive—thus opposing an impassable barrier to the confusion of species, which would inevitably result, were these mule or hybrid beings capable of continuing their race. The converse of the proposition is

equally true. Animals of the same species, however dissimilar in external appearance, habits, and manners, are capable of breeding with varieties of their own species in illimitable progression, and every successive crossing of breed may result in new modifications of form, and in improved physical and intellectual conditions."

The celebrated Dr. John Hunter observes, that "the true distinction of species must ultimately be gathered from their incapacity of propagating with each other, and producing offspring capable of again continuing itself."

Dr. Prichard remarks, that "if different species mixed their breed, and hybrid races were propagated, the animal world would soon present a scene of confusion. Its tribes would be everywhere blended together, and we should find more hybrid creatures than genuine and uncorrupted races."

Mr. Lyell, whose authority in matters of fact is unquestioned, though some of his geological theories are unsatisfactory, remarks that "it may be laid down as a general rule, admitting of very few exceptions among quadrupeds, that the hybrid progeny is sterile, and there seem to be no well-authenticated examples of the continuance of the mule race beyond one generation." After canvassing all the well-authenticated facts respecting the mixed progeny of any two species in the animal or vegetable kingdom, he concludes, that it cannot be shown that any hybrid or mule race, which, as you know, are the names applied to the offspring of any two distinct species, has ever been produced, capable of permanent reproduction and self-perpetuation of its family.

It is, then, beyond all question, a law of nature, that no two distinct species of animal can produce offspring capable of successive reproduction. Look now at the application of this rule among all the races and varieties of human kind, of all sorts and sizes, of all characters and colors, of all faces and features, of all names and nations, and the

question is at once and for ever settled, nor can a doubt ever be raised, that all the nations, varieties, and races of man are one and the same species, sprung from one and the same origin, offshoots from one and the same stock.

446. *Language of mankind.*—We have yet other proofs and illustrations of our proposition. We must notice some curious facts discovered by the comparison of languages. The gift of speech distinguishes man from all other species of animal. Some species can imitate sounds, as the mocking bird and parrot, but none can truly talk. Sir Charles Bell says he has often been asked, by men of the first education and talents, whether any thing really deficient had been discovered in the organs of the orang-outang, to prevent him from speaking, and he answers the inquiry by saying, that even if the ape had all the apparatus of speaking, he would still lack the impulse, the internal faculty or propensity. The power of speech was given to man, as a specific endowment of the race, and it is possessed in perfection by all the varieties of the race.

Schlegel goes still farther. He not only considers the faculty of speech a specific endowment to man, but that language itself is an individual gift to man. He does not, however, speak of language as given to man by Divine communication, but he considers the mind of man so organized as necessarily to produce on his first appearance the well-ordered structure of language, with all its roots, pronunciation, and even *written character*.

Dr. Wiseman, to whose admirable lectures we are indebted for most of our facts respecting the comparison of languages, says that "languages grow not up from a seed or sprout. They are, by some mysterious process of nature, cast in a living mold, whence they come out in all their fair proportions. That mold is the mind of man, variously modified by the circumstances of his outward relations."

It would, indeed, seem, that while language is mutable

and improvable in some respects, it is fixed and unchangeable in others. New words may be introduced from other languages, or made by composition, and variations in the forms of sentences and in spelling words are admissible. But the structure, the cases, the tenses, the moods, the fundamental principles of the grammar, cannot be altered. The Hebrew and Arabic, and kindred languages, have never generated a present tense, or compound and conditional tenses and moods. Nor have those who speak those languages, though living for ages in contact with people using more perfect alphabets, and fully owning the immense difficulties of one without vowels, ever succeeded in introducing them into their own dialects, but resort, to this day, to the clumsy expedient of troublesome points. There is something mysterious in the different grammatical structure of languages. We cannot account for it. We have in our own language many Anglo-Saxon words; but where is the Anglo-Saxon structure? and whence did we derive our peculiar English structure? and who invented it? It is not, like our words, the result of gradual improvement and accessions; for the essentials of the language, the structure, the fundamental grammar, were as perfect in the days of Chaucer and Spenser as in those of Addison and Macaulay. The Italian differs in words but little from the Latin. But its grammatical structure is totally different. It has lost the Latin declensions, and the passive voice of verbs, and assumed a totally-different mode of conjugating the active verb. How and whence came the Italian grammar? Were it not for differences in the grammatical structure of their languages, the nations of modern Europe might understand each other, for many of their words are nearly the same; and the origin and cause of this grammatical structure, peculiar to each language, are inscrutable mysteries. We know, in most cases, the time when any particular language did not exist. We know, again, some subsequent time when

it did exist. But the generation of the language, and the precise time and manner of its birth, are concealed in the deepest mystery. On the whole, I am inclined to believe, with Schlegel, that language in the beginning was spontaneously and involuntarily produced by the human mind, acting under laws immediately superintended by divine Wisdom, and that the same phenomena are still repeated, often as the circumstances of the human race, in connection with the wise designs of Providence, require.

447. *Comparison of languages.*—The Bible informs us, that as all men were originally of one species, so they had one speech and one language, which was miraculously confounded. If we are correct in our inference, that the production of language was a species of miracle, it might seem but natural that the same kind of means should be used in so confounding it as to produce the desired and intended effect—a separation and dispersion of mankind.

The modern philosophers, not less than the builders of Babel, have been confounded by the multiplicity and variety of languages among men. Attempts to investigate this subject have given rise to a new science, which the French call *linguistique*, and the English, comparative philology. As nations may be classified by the comparison of their languages, some call the science ethnography. A great many other circumstances, besides language, should, however, be regarded in classifying nations. The science, however, call it by what name you please, has given us many interesting facts and results, for an account of which I am wholly indebted to the lectures of Dr. Wiseman, I having never been so fortunate as to meet with any other work on the subject. The following are some of these results. It is found, by examination and comparison, that all the various languages and dialects, used by various, separate, distinct, and wholly-independent nations, extending over a great range of country, are so connected, either by

similar words or by similar grammatical structure, or by both, as to be all traced to one great family. One of these families is called the Indo-Germanic, or Indo-European. It includes the Sanscrit, or ancient and sacred language of India, the ancient and modern Persian, Greek, Latin, and all the languages of modern Europe, except that of Hungary and Finland. You would be surprised to find certain words running, with slight variation, through all these languages. Take, for example, that word longest remembered by you—the word that often, in your wildest moments and most heedless career, throws a spell over your heart—*mother*. Trace it through the languages of this family: Latin, *mater*; French, *mere*; Spanish, *madre*; and Persian, *mader*. Compare, also, the English word brother with the Persian *brader*, son with *sunu*, and doctor with *dokhter*. Compare, also, the English word serpent with the Asiatic *sarpan*, brow with *brouwa*, eye with *eyumen*, star with *stara*, river with *arrivi*, and lip with *lib*.

Look again at some of the irregularities of our language. Where do we find our comparative *better*? Certainly not from *good*. But in the Persian we have *beh*, *behter*, *behst*, with precisely the same meaning as our good, better, best. So we have, in the same language, *bad*, *badhter*, *badst*, equivalent to our bad, worse, worst. How many more perplexing irregularities of our own language might be explained by comparison with the Persian and Sanscrit, I know not.

Every scholar must have observed the irregularities of our verb *to be*. But similar irregularities of that same verb are found in all the languages I have ever examined. A second great family of languages, to which many varieties, ancient and modern, are traced, is called the Shemitic. It includes the Hebrew, Arabic, Syriac, and Abyssinian. These are known by most scholars to be so similar, that when you have learned one, the others may be very easily acquired.

Another family may be called the Polynesian, though it

is usually known as the Malay. It includes the varieties of Malay, China, Java, and all the islands of the Indian Archipelago. In all the languages of this group there is said to be a tendency to a structure purely monosyllabic, with the rejection of all inflexion, and with unlimited variations by accentuation.

The languages of Africa have not been satisfactorily examined, and no results are reported.

The American family contains innumerable dialects, but all yet examined are alike in grammatical structure, particularly in the peculiarity of modifying verbs by inserting syllables. Eighty-three languages of distinct Indian tribes furnished, on examination, one hundred and seventy words, whose roots appear to be the same. These words resemble words found in the European, Asiatic, and African families. Malte Brun has noted similarities between several American, Indian, and Asiatic words.

Having traced all known languages to a few great families, the next attempt was to connect the primary families together. In this effort success has been most encouraging. There are found certain words which run, not only entirely through all the members of the same family, but through all the families. Of these are the numerals one, six, and seven, which are found, with slight variations, in every known language. It has also been found, that two very dissimilar languages are sometimes intimately connected by a third, which resembles both. Thus the modern Coptic, which is known to be the same as the ancient Egyptian, is the connecting link between the European and Asiatic languages. This Egyptian language was long considered insulated, and void of connection with those around it; but, on examination, it is found to present points of contact with the two great and principal families of the civilized world—the Indo-European and the Shemitic. It properly belongs to neither family, but forms the connection between them, so that by

its interposition these two great families appear no longer separated, but linked in a mysterious affinity, grounded on the essential structure and most necessary forms of the three.

Further examination may link together other members of the great families, and the families themselves with each other, so as to connect all the languages of the earth in one harmonious whole.

The results of the science of languages, so far as they are yet developed, afford strong confirmation of the Scripture account of the unity of species, and of the original language of the human race, and of the violent confusion of the language, and consequent dispersion of the race, at the building of Babel. The investigations on the subject do not favor the probability of finding, either among ancient or modern tongues, the original language of man. Schlegel observes, that, "with our present senses and organs, it is as impossible for us to form the remotest idea of that speech, which the first man possessed before he lost his original power, perfection, and worth, as it would be to reason of that mysterious discourse, whereby immortal spirits send, on wings of light, their thoughts across the wide space of heaven." All search after the original language would be as fruitless as that for the place of the garden of Eden, or that of the alchemist for the philosopher's stone. Probably the mother language perished by the shock that gave birth to her children. All languages examined seem related fraternally, rather than parentally. From their structure there is afforded a strong presumption, that they separated from the original source not voluntarily and gradually, but compulsively and suddenly.

Thus is the truth of the sacred narrative confirmed, to a degree, and in a manner, and by a science least expected.

448. *Oneness of the moral principle in man.*—I present you one more proof of the unity of the human race, the

oneness of the moral nature, the sameness of conscience. We have shown (§390) that man is distinguished from the brute by conscience. If we cannot now show the oneness of conscience, we can by it infer to demonstration the unity of the species.

We will first answer some of the general objections, which are frequently brought against the uniformity of the decisions of conscience. It has been alledged, that there is an exceeding diversity of the moral judgments among men; that some nations applaud theft and robbery, while others punish them; some sanction the slave-trade, others punish it as piracy; some expose their infant children and kill their old men, while others protect them at the sacrifice of their own lives; some defend retaliation, revenge, and assassination; some sacrifice their children to idols, their widows on the funeral pile, and themselves by suicide; some, apparently good men, have persecuted others for opinion and religion's sake, inflicting all the tortures of the inquisition and martyrdom.

It is alledged that there is, in the whole catalogue of vice, hardly a crime which has not been practiced and defended in some nation and age of the world; that out of the multifarious decisions of conscience no consistent code of virtue can be framed, and, therefore, there is no proof of oneness in the original moral sentiment of nations.

The facts contained in these allegations are conceded, but the conclusion drawn therefrom is not. It is said by some one, that "every error is a truth abused." We are inclined to agree in this sentiment, and we propose a kindred one—*every vice is a virtue abused*. Many actions are so complex as to have various opposite results of good and evil, of which it is not easy to trace the consequences. When an action is thus complicated by a mixture of good and evil, some individuals and some nations fix on the good, and others on the evil. Some practice, sanction, and applaud

the act on account of its good, while others avoid, condemn, and punish it on account of its evil. The same action may, therefore, be approved in one age or one country, and disapproved in another age and another country, according as the one people look on the good side, and the other on the bad. In no age, and in no country, and by no variety of men, has ever an action been practiced and approved on account of its evil tendency, or avoided and condemned on account of its good tendency. Wherever and whenever a practice deemed by us vicious has been approved by the moral sentiment of any people, it has been done for its good, and in spite of its evil tendency. The Spartans applauded and rewarded theft, not because they approved of the violation of the rights of property, but because they deemed the habits of vigilance and stratagem, which successful stealing demanded, virtues among a warlike people. Property with them was of little value. Warlike habits were in high repute. To promote such habits they sanctioned stealing, in spite of its evil tendency. The African slave-trade was not sanctioned in former centuries on account of the sufferings and cruelty which its prosecution inflicted on its victims, but on account of some fancied necessity and expected good. On the authority of Washington Irving, in his life of Columbus, it appears that the slave-trade was projected and sanctioned by the Spanish government, and negro slavery introduced in the West Indies, from which it spread over all the Spanish American possessions, on the earnest recommendation of one of the most benevolent and kindred of Christian missionaries, with the express, avowed, and sole design of relieving the poor native Indians from servitude and labor. This good man, by looking only on one side of a question, saw only good, and therefore approved it; while we, looking on the other side, see only evil, and therefore condemn it.

Among some of the ancient and warlike nations, feeble and sickly children were exposed in the woods to die, or to

be devoured by wild beasts. This was sanctioned by law, and by public sentiment, not because of its cruelty and its violation of all the natural affections of the heart, but because the interest of the state and the cause of patriotism seemed to require the rearing only of a vigorous and healthy race. Some savage tribes now kill off their sickly and feeble old men, and the moral sentiment of their people sanctions it, not because of the unfeeling cruelty which we see in the act, but because they deem it kindness to the old man, to put him out of his misery, just as we would a favorite but mortally-wounded dog, or a sick horse.

Retaliation, revenge, and private assassination are sanctioned in some communities, in spite of their evil tendency, just as, among ourselves, war, invasion, and murderous battle are sanctioned on account of the glory, and national honor, and patriotism evolved in the process. The Hindoo mother drowns her favorite child in the Ganges, and her moral sentiment approves the act, not because of the cruelty and misery involved therein, but because she deems it the highest virtue to sacrifice her best affections, the very child of her heart, to appease the imaginary deity she worships. The moral sentiment of the Hindoo widow requires her to lie down and die on the funeral pile of her husband, not for the sake of violating the first law of nature, self-preservation, but for the sake of manifesting her respect for her husband, and of complying with the long-established customs of the country. Persecution has been allowed, yea, required by the Christian Church, and sanctioned by the moral sentiments of the age, not on account of its violation of the rights of conscience, but for the good of the Church, and in some instances by torturing the body to save the soul of the unfortunate heretic.

In all these cases, and probably in all others, in which practices evidently wrong and criminal are sanctioned and approved by the moral sentiments of any people, it will be

found that the act is one of complicated tendency—of mixed good and evil—and that it is approved by those who, from the general circumstances of society, or from political errors, or from wrong theories in morals, or from false notions in religion, look only at the good, and overlook wholly the evil tendency.

The question of the amount of guilt contracted by those whose decisions of moral sentiment are thus perverted, enters not into our argument at the present time. We are only explaining in what way the diversity of decision may be reconciled with the oneness in nature of the moral principle, or, in other words, the conscience of mankind.

We may remark, before leaving this point, that the diversities of decision of the moral sentiment among men are no greater between the different varieties, or races of men, than between individuals of the same variety, or nation, and even between the same people in different ages. We may assert even more. The difference of the decisions of the moral sentiment of any two most diverse nations is often no greater than may frequently be seen in the decisions of the conscience of any individual at different periods of his life.

Notwithstanding the decisions of the moral sentiment of mankind exhibit diversities in detail, we affirm that, fundamentally and in principle, they are uniform among all races, varieties, nations, tribes, languages, and ages of the world. There is no dispute among mankind about the rule of human action, but about the application of the rule. No nation nor people has ever doubted that virtue should be practiced, and vice avoided. But some question has often been raised on the claims of certain acts to be considered virtues; and on the decision of this question there has appeared some diversity of opinion. On the question of the binding obligation of virtue, there has never been any diversity of sentiment whatever. If, says Sir James M'Intosh, one of the clearest writers on ethical philosophy, "we bear in mind

that the question relates to the coincidence of all men in considering the same qualities as virtues, and not to a preference of one class of virtues by some, and a different class by others, the exceptions from the agreement of mankind, in their systems of practical morality, will be reduced to absolute insignificance, and we shall learn to view them as no more affecting the harmony of the moral faculties, than the resemblance of the limbs and features is affected by monstrous conformations, or by the unfortunate effects of accident and disease in a very few individuals."

We venture to affirm, that there is not a country nor a people on earth, where and among whom the intentional producer of unmixed evil is preferred on that account to the intentional producer of what good he is capable of producing; where and among whom it is considered more meritorious to hate than to love a benefactor because he is a benefactor, and to love rather than hate the betrayer of his friend merely because he is a traitor; where and among whom justice, humanity, and gratitude, are for their own sake proscribed, and falsehood, cruelty, and fraud, for their own sake approved.

Were all men equally enlightened in the circumstances, or the essential relations and tendency of any action, the consciences of all would come forth with the same moral decision. Even now, in every case where the intellect is enlightened, the moral sense unfettered by association, and the judgment uncramped by partialities of interest, or by the prejudice of habit, Conscience, says Dr. Chalmers, "is found to speak the same language; nor, to the remotest ends of the world, is there a country or an island, where the same uniform and consistent voice is not heard from her. Let the mists of ignorance, and passion, and artificial education, be only cleared away, and the moral attributes of goodness, and righteousness, and truth, be seen undisputed, and in their own proper guise, and there is not,

throughout earth's teeming population, a conscience which would refuse to do them homage." -

In connection with the oneness of the moral sentiment, I may refer to the uniformity of religious experience. The missionary of the Christian faith finds access to the heart of all men by the same means, and urges them to a religious life by the same motives. The same story of the cross arrests the attention and moves the heart alike, of the Indian, the African, and the European. Religious experience in all its course, from the strong conviction and deep penitence for sin, to the earnest hope and full assurance of faith, is one and the same, whether felt by the proud European lord of a thousand hills and a million serfs, or the abject Ethiopian, bending with toil beneath a burning sun, and lashed by the whip of his merciless overseer.

I have now presented you, in the order in which they naturally occur to me, the principal facts in my possession bearing on this great question, and have drawn therefrom such arguments for the unity of the human race as seem to me legitimate and fair. There are, however, as I have reason to believe, stores of facts to which I have not now access, all bearing on the same question, and sustaining the views I have given, and confirming the opinions I have advanced. I trust, however, sufficient fact and argument have been presented in this lecture, to furnish the inquiring and candid mind with a protection against the insidious approaches, and a defense against the open attacks of those who, through pride, "philosophy, falsely so called," and vain deceit, would withdraw the support of revelation, and overthrow the very foundation of our hope in Christ, the "Savior of the world."

LECTURE XX.

MISCELLANEOUS AND CONCLUDING SUGGESTIONS.

Verification of some points of Scripture history from hieroglyphic inscriptions on the monuments of Egypt—Later sacred history—Harmony between the teachings of nature and of revelation on the character of God—Harmony between the teachings of revelation and the moral instincts of man—Universal adaptation of the doctrines and morals of Christianity to the human race—Conclusion.

449. *Verification of some points of sacred history from hieroglyphic inscriptions on the monuments of Egypt.*—The historical records of the Bible consist of two parts—the ancient and the modern. The ancient extends far back beyond all other written history. Twenty-five centuries had passed away in the history of the world, before Moses began to record his annals. For information of facts, which transpired before his day, he might have been indebted to tradition, to older records now lost, and to Divine inspiration. We have already seen how three of the leading events described by him, as occurring before his time—the creation, the deluge, and the dispersion of mankind from one and the same origin and location—are verified by science. From the time of Moses to the time of Herodotus, about one thousand years, the only cotemporaneous written history of the world we have, is that contained in the Bible.

Herodotus, as you are of course aware, is the oldest historian, except those of the Bible, whose works have come down to our times. He was nearly cotemporary with Xerxes of Persia, the last Tarquin of Rome, and the Jewish prophet, Ezra. The historians whom he consulted, and whose works are lost, were only a century older than he. Of course, all that Herodotus says of events before his time is founded mostly on tradition, and we cannot expect to find much in his history to verify that of Moses and his successors to the time of Ezra.

But another source of verification has been opened to us, in modern times, more convincing and demonstrable than any written, even cotemporaneous, history could be. The banks of the Nile are known to have been, from the time of Moses to that of Herodotus, teeming with an innumerable population of intelligent and civilized people. They have left to posterity their monuments of pyramids, and gigantic columns, and temples, and tombs, in number and magnitude such as the mind of no other race of men has ever conceived. These monuments, mostly formed of imperishable granite, are covered with inscriptions, which, for many centuries, the learned world strove in vain to read. No key could be found to unlock their hidden meaning, no thread to guide the explorer through their labyrinth of knowledge and wisdom. Accident at last furnished the means of discovering the long-lost key.

In digging for the foundation of a fort near Rosetta, by the French expedition in the time of Napoleon, the workmen discovered, buried some distance in the ground, a stone, an irregular block of basalt, containing an inscription in three different languages, Greek, hieroglyphic, and Coptic; which latter is fully identified with the ancient language of Egypt. Learned men immediately plied themselves to the task of discovering from these inscriptions the hieroglyphic alphabet. The Greek inscription could, of course, be easily read. The Coptic yielded without difficulty, and was found to be the same as the Greek. Knowing that it was customary, in ancient times, to write inscriptions in several languages—as you will recollect the inscription over the cross of Christ was written in Hebrew, and Greek, and Latin—the learned reasonably supposed the hieroglyphic inscription might be merely a copy of the others. Long and careful examination verified the supposition. The three inscriptions were proved to record the same event in Greek, in Egyptian, and in hieroglyphic.

By comparing the hieroglyphic with the other two, word with word, and letter with letter, the whole mystery of the hieroglyphics was explained. The hieroglyphic language is found to be not wholly emblematic, as was formerly supposed, but partly emblematic, and partly alphabetic.

It was the discovery, from the Rosetta stone, of the alphabetic key, that opened the whole field of hieroglyphic literature. It is now known what letters and words each hieroglyphic mark or character represents, and there is little more difficulty for those who have studied the language, in reading Egyptian hieroglyphics, than in reading Hebrew or Greek.

Champollion, a Frenchman, and Wilkinson, an Englishman, have collected from the monuments of Egypt a large amount of hieroglyphic literature, copying and publishing inscriptions from the temples and other remains of monuments scattered all over the country. Rossellini, an Italian, the companion of Champollion in the literary expedition sent to Egypt at joint expense, by the French and Tuscan governments, has published several volumes of results drawn from their discoveries. I have never seen the publications of Champollion, nor Rossellini, nor Wilkinson. I wish I had them. I have, however, occasionally seen extracts and notices of results. The most extended notice, and the best summary of results I have read, may be found in Wiseman's lectures.

Among the numerous points of coincidence between Egyptian hieroglyphic and Jewish written history, discovered by Champollion and Rossellini, and noticed by Wiseman, I will select three, which seem to me demonstrably conclusive of the truth and accuracy of the historical facts of the Bible.

The first point relates to the history of Joseph and the Israelites in Egypt. It is noticed by Champollion, in an original letter to Dr. Wiseman, and afterward more fully

elucidated by Rossellini. You will find, in the latter part of the forty-sixth chapter of Genesis, that Joseph, on meeting his father and brethren, who had come down to Egypt to live, instructed them to say to Pharaoh, when asked of their trade and occupation, that they were shepherds, their trade having always been about cattle. Joseph intimates, that if they give Pharaoh this answer, he will locate them in Goshen, *the best part of Egypt*, and assigns for this preference in giving them for their home the very garden of the country, the very singular and inexplicable reason, that "*every shepherd is an abomination to the Egyptians.*" Now, that an Egyptian king should favor a foreign people, by locating them in the best part of the kingdom, merely because their trade or business was an abomination to the native people, appears most strange. Nor does any ancient written history explain the matter.

The labors of Champollion and Rossellini have brought to light the whole history of the ancient Egyptian kings. The date of the beginning and end of each dynasty or family, and of the accession and death of each member of the dynasty, is satisfactorily determined. From the hieroglyphic records it appears, that, at the time Jacob and his family emigrated to Egypt, the country was governed by a foreign race of princes. They were called the Hyksos, or shepherd kings, and are supposed to be of Scythian origin. They had conquered and expelled the native kings, and ruled themselves over the native people. Now, it was perfectly natural that these foreign and usurping princes, of a shepherd race, should favor a foreign emigration of the same trade and habits as themselves. It was also perfectly natural, that the native population—the *Egyptians*—should *abominate* and hate every shepherd, and every shepherd race, since by such a race had their country been invaded, their native princes conquered and expelled, and themselves oppressed.

This discovery further explains why the king ruling in Joseph's time should avail himself of the distress of the native people, through famine, to buy up all the land which before had been held by the native people. He thus reduced the native population to the condition of vassalage, greatly resembling that of Europe in the middle ages. All those facts related in the forty-seventh chapter of Genesis, from the thirteenth to the twenty-seventh verse, would have for ever remained totally inexplicable, but for the discovery of the hieroglyphic mystery.

This discovery also explains another fact connected with the history of the Israelites in Egypt, some centuries after the time of Joseph. In the first chapter of Exodus it is said, "Now there rose up a new king over Egypt, who knew not Joseph." The narrative continues to give an account of the severe measures he took to oppress and reduce the people, lest, in case of a war breaking out, they should join the enemies of Egypt. Now, Champollion discovered, by hieroglyphics on the monuments, that this new king, who *knew not Joseph*, was the first of a new dynasty. There had been a revolution. The shepherd kings, who had ruled the country for some centuries, were expelled. The descendants of the native princes, dethroned by the shepherd race, were restored. This new king is called, on Egyptian monuments, Ramses. He, as Champollion says, "*ought not to know Joseph, the servant of the usurping kings.*" He would consider all the race of Joseph enemies; and, as he and his kingdom were yet greatly harassed with fear, lest the expelled, usurping, Scythian race should return, and strive to reconquer the country, he had reason to fear the Israelites might join his enemies; and he determined, therefore, to reduce them to servitude, and to diminish their numbers and their power.

The second point of coincidence is very curious. It is not, in fact, a coincidence. but an explanation, by hiero-

glyphic, of an omission in sacred history. All ancient histories, except that of the Bible, abound in glowing accounts of the mighty exploits of Sesostris—an Egyptian king—a great conqueror, who overran and subjected many nations, including Palestine. The Jewish history says not one word about him. Now, as he must have passed over the very country of the Israelites, the omission of all reference to his name or exploits in sacred history was long wholly unaccountable; and I think the fact has been urged by skeptical writers as an objection to the credibility of the sacred narrative. But here, again, hieroglyphic discovery comes to our aid. Champollion has identified the Pharaoh, under whom Moses delivered the Israelites, with Ramses V, called, on Egyptian monuments, Amenophis. The year of his death is marked by Egyptian chronology, and is the same as that of the exodus of the Israelites from Egypt. Sesostris was his son and successor, and his conquests were made while the Israelites were wandering in the wilderness. Of course, Moses had nothing to do with Sesostris nor his exploits, and probably knew nothing about them, as the whole affair transpired while he, with his people, was as much excluded from the world, as though he had been governor of Oregon. It would be very unreasonable, under such circumstances, for the exploits of Sesostris to form a part of such a narrative, and for such purposes as that of the Bible.

The third point respects a confirmation of a later portion of Jewish history. In the fourteenth chapter of the first book of Kings, and in the twelfth of second Chronicles, we are informed that Shishak, king of Egypt, came against Judah, in the fifth year of Rehoboam, with twelve thousand chariots, sixty thousand horsemen, and a countless host; that, after having taken the fortified cities of Judah, he was approaching Jerusalem; that the king and people of Israel, in fear, humbled themselves

before the Lord; that the Lord pitied them—promised not to destroy them, but to grant them some deliverance; but, that they might know the difference between his service and the service of the profane princes of the earth, he would cause them to become Shishak's servants. "So Shishak came and took away the treasures of the house of the Lord, and the treasures of the king's house. He took all. He carried away, also, the shields of gold which Solomon had made." In the magnificent temple of Carnac the exploits of Shishak, or Sheshonk, as the name is properly written, are recorded in full, in sculpture and hieroglyphic. Champollion has published an engraving of the scene, which Wiseman has, in part, copied. Shishak is exhibited as holding, by the hair, a crowd of kneeling figures, heaped together, and with his right hand raised up, ready, at one blow, to destroy them all. Another crowd of captives, with their hands tied behind them, is driven forward toward him. Among the captive kings of this crowd is one, whose physiognomy is unmistakably Jewish, with beard and all that distinguishes the Jew. He bears a shield, on which are inscribed hieroglyphics. The hieroglyphics read, according to the key discovered, "*the king of Judah.*" Thus we have a demonstration of the verity of Scripture history.

If I had the original works of Champollion, Rossellini, and Wilkinson, I might, I doubt not, present you other verifications, as demonstrable as these. There is no mistaking, nor evading, nor in any other way getting over such evidences of the truth and accuracy of the inspired record. The simple fact of such coincidence is sufficient. No argument is required. I venture to affirm, that not a Greek or Roman history can present clearer points of absolute verification than those presented by sacred history; and yet Grecian and Roman history has the advantage in time, being centuries younger, and, of course, presenting numerous points

easy of verification. Leaving the question of Divine inspiration entirely out of the account—looking at sacred history merely as a human composition, to be judged by the ordinary rules of criticism—I should be obliged, on scientific grounds alone, to believe the sacred history far more correct, and minutely accurate, than the history of Herodotus, or Xenophon, or Livy, or Tacitus.

450. *Later sacred history.*—There are other events of Jewish history of deep and romantic interest, which, if they needed it, might be verified in many ways. The story of the captivity in Babylon is full of interesting incident, and the circumstances are recorded with so much detail, as to furnish numerous points of coincidence with profane history. It should always be remembered, however, that we have no cotemporaneous history of those times—the oldest historians, whose works are preserved, having lived nearly a century later than the period when the Jews returned from captivity. But Herodotus lived so near those times, that he may reasonably be supposed to have received tolerably-correct information from tradition and from other sources. We might by going into detail show the Scriptures, in their record of events, and in their allusions to the manners, habits, and customs of the Assyrians, Medes, and Persians, agree with all the well-authenticated records of ordinary history and tradition. But, should we proceed further in this process of verification, we might find ourselves, before we are aware, writing a volume of ancient history. It is not necessary for our purpose to notice any more points of coincidence between sacred and civil history, whether hieroglyphic or written.

I did intend, when I commenced writing out these lectures, to present an epitome of the evidences of Christianity. I should go over that holy ground with deep interest to myself, and I trust with interest and profit to the reader. But my manuscript has already become as large

as I intended, or now desire to make it. I must, therefore, leave the whole field of the evidences of Christianity unentered, and the subject untouched. It is true, many treatises have been written and published on the subject, some relying on one, and some on another kind of argument, and some accumulating a miscellaneous mass of facts, without order and without arrangement. I am not sure but the times need a new treatise, of an eclectic character, presenting in a clear and succinct form the strong points of Stillingfleet, Paley, Watson, and others, with such additions as the progress of science for the last century has accumulated. Should it be thought expedient to go into such an enterprise hereafter, I hold myself ready to advance, and I invite you to follow me. But at present we must refrain from extending these lectures over so much ground.

I cannot, however, dismiss the general subject of natural and revealed religion, which has engaged our attention so long, and part with you, until I have briefly called attention to a few miscellaneous thoughts.

451. *Harmony between the teachings of nature and of revelation on the character of God.*—We have seen that omniscience, omnipotence, omnipresence, goodness, and eternity of existence, are inferred from nature, as essential attributes of the Deity. We have but to look into the book of revelation to see that these attributes are there strongly and repeatedly affirmed, often in the sublimest strains of poetry. The greatness, the immensity, the power, and the infinite wisdom of God, are subjects in which the Hebrew poetry is always conversant and always excels. It is infinitely superior to the poetry of any other nation. I might give you pages on pages of examples, selected from the prophets, of poetry, such as Homer never conceived—poetry, such as no modern writer has ever dared to imitate. But, should I attempt to quote the lofty descriptions of God and his attributes from the Hebrew poets, I would not know where

to begin nor end. If you desire to see some fine observations and examples on this subject, I would refer you to Lowth's Lectures on Hebrew Poetry, although it seems a pity that he has given his examples in Latin, rather than in our own good and noble English.

In section 382 we inferred from nature the unity of the Deity. History shows that there is in the human mind a strong tendency to multiply deities. On this point, therefore, revelation is explicit and positive. The sacred writers seem to labor incessantly to impress this truth on the mind of the people. It would seem, from its frequent repetition, that this truth was deemed of more importance by holy men of old, who spoke as they were moved by the Holy Ghost, than any other, or, indeed, all others.

There are revealed in the Bible some attributes of God, which could not be inferred from nature. Of these we may mention justice, mercy, and holiness. Revelation represents the Deity as a moral governor of the universe, administering justice with an impartial hand, and meting out to every moral agent the exact reward of his works. Though this character of God might be inferred from the moral nature of man, yet there is nothing in the laws of mere physical nature from which we could infer it. For a clear understanding of this attribute we are indebted wholly to revelation.

Mercy we should never infer from the laws of nature. Goodness is seen in a thousand instances in the determining and establishing of those laws, but mercy in remitting the penalty of violation is nowhere in nature known. Whoever violates nature's law must suffer the penalty attached thereto; nor is there any mode, manner, way, or means of escape. But revelation presents us the Deity in a new character—that of a merciful and forgiving God. He is proclaimed as the "Lord God, merciful and gracious, long-suffering, and abundant in goodness and truth, keeping

mercy for thousands, and forgiving iniquity, transgression, and sin." His mercy shines glorious in the great plan of redemption, through Christ, in whom the sinner may have hope of pardon and forgiveness.

Of holiness, or moral purity, we should form from physical nature no conception. This falls wholly within the province of revelation. Some of the finest passages of sacred poetry are descriptive of this divine attribute. Though the attributes of justice, mercy, and holiness are additional, yet are they not in opposition to those inferred from nature. And they are in perfect harmony with the moral sense and religious consciousness of man. However man may conduct himself, he feels, that to "deal justly, love mercy, and walk humbly with his God" is the instinct of his moral nature, and that it should form his law and rule of conduct. It is thence easy to infer the justice, mercy, and holiness of that Being, who has given man such instincts. While, therefore, we could not infer these attributes of Divinity from physical nature, we should yet be forced to infer them from our own moral nature. It is thus that the utmost harmony exists between revelation and external and internal nature in their teachings of the attributes of the divine Being.

452. *Harmony between the teachings of revelation and the moral instincts of man.*—The principle to which we have just alluded—harmony between revelation and the moral suggestions of man—extends to all the doctrines of revelation. It cannot be uninteresting for us to notice some of these harmonies.

Revelation explicitly teaches us, that man, though created a noble, worthy, and good being, occupies not now that high and holy state in which God placed him. He fell, ignobly and sadly fell, and lost thereby that pure and righteous nature, which God gave him. In consequence of that fall, we are taught, that very early in the history of

the race, the "wickedness of man became great in the earth, and every imagination of the thoughts of his heart, was only evil and that continually." Some two thousand years after this, it was also said, that the Lord looked down from heaven on the children of men, and found them all gone aside, not one of them doing good, not one. Six centuries after this, even under the dispensation of the new covenant, this same truth was affirmed, and it was said, there were none righteous, no not one, but they were all gone out of the way.

Now, this doctrine of revelation is in harmony with the instincts, the suggestions of our own moral nature. What man is there, that lives, and is not conscious of the depraved and sinful tendency of his nature? What man does not see and feel a great difference between what he does and what he ought to do? what he is and what he ought to be? We know by our own moral sense that we are all gone out of the way; we have deviated far and wide from that straight and narrow path of virtue, which leads from earth to heaven. We know that there is in us a propensity to sin, a tendency to evil; that when we "would do good evil is present with us." We see and we approve the good, the right, and the true; but we love and we follow the evil, the wrong, and the false.

Coetaneous with the fall of man was the revelation of the plan of redemption. "The seed of the woman shall bruise the serpent's head" conveyed to the understanding of man the idea of a restorer, and introduced Hope, with her cheerful light, into the darkened chambers of his desponding heart. From that moment hope never forsook the race of man. The hope of a restorer cheered and encouraged the descendants of Israel, while they were toiling in slavery on the banks of the Nile, to build the pyramids, and in later times hanging in sadness their harps on the willows by the streams of Babylon.

The light of hope, collected from vague and uncertain tradition, glimmered also in the mind of the dispersed and uninstructed people of the nations. The poets of eastern clime, and of classic Greece, and of manly Rome, had glimpses of a better day, a brighter era, when the iron age should cease, and the glorious, golden age of primeval virtue return.

Connected with the plan of redemption, as undertaken by the great Restorer of fallen humanity, were promises of an improved and highly-exalted condition of man on earth. Under the reign of the Messiah, the angry passions of man should be subdued to peace and love; for the wolf should dwell with the lamb, the leopard lie down with the kid, the cow feed with the bear, while their young were lying down together, and the infant child should play, unharmed, amidst ravenous beasts and poisonous serpents. That day should be remarkable for the power of moral truth; for the knowledge of the Lord should cover the earth as the waters do the sea, while the glory of the Lord should be revealed, and all nations should see it together. This glorious day should be perpetual; for, though the heavens might vanish away like smoke, and the earth wax old like a garment, yet should the salvation of the Lord be for ever, and his righteousness should not be abolished.

Such are the revelations of prophetic inspiration respecting the future condition of human society, and all the lessons of history, and all the suggestions of man's intellectual and moral nature are in harmony with these teachings of inspiration. Man knows and feels, that through the regenerating influence of divine truth, there are infused into his heart the elements of illimitable improvement. In this conviction he labors in the work of human improvement, whose beginning he knows not, and whose end he expects not to see. He takes up the work where his predecessor left it, toils on for his day, then goes to his reward, and leaves the unfinished temple for others to complete.

The millennium of prophetic revelation has its counterpart in the ideal of the human heart. It is true, man sometimes fails, in his longings and hopes of better days, to recognize the connection between his own inward and spontaneous faith and the prophecies of holy record. He, therefore, fails to perceive and to use the only means which God has ordained to accomplish the great and blessed work of human advancement. In the universal adoption of Christian principle, and the universal practice of Christian virtue, alone can our hope of the perfection of humanity be realized. Between the moral precepts of revelation and the moral sense of humanity there is wonderful harmony. The law of morals revealed in the Bible and the law written on the heart of man are one and the same. We do not mean that all men by nature practice the precepts of moral law; nor do we mean that all men, informed by revelation, practice those precepts; but the conscience, the moral sense of the human race, approves the practice of those precepts.

It is remarkable that the great leading principle of Christianity—love, the love of human kind, the love even of our enemy, such love as forbids retaliation and revenge—was equally unknown to “Moses and the prophets,” and to ancient classic moralists. One of the purest-minded of the Greek philosophers and moralists, could advise a young friend and pupil to labor *to excel in doing evil to his enemies*, as well as in doing good to his friends. This unchristian rule of action, so gravely laid down by the philosopher, can hardly be equaled in the poetic imprecations of the Hebrew Psalmist. The fact is, un instructed human nature never did, and never could, conceive the idea of forgiveness of injury. Nor did Moses and the prophets reveal it. But when once the idea was projected and published in the code of Christian morals, the moral sense of man approved it. I have never seen the man, nor have I ever heard of

one, who, well-educated and enlightened in science, philosophy, and history, did not approve in his conscience of the entire code of Christian morals. Exception is taken to no part, however small, of the system. However far our practice may vary from Christian morality, our heart, our conscience, our moral sense must approve and sanction it.

This perfect harmony between revelation and the enlightened moral sense of the human race, appears to me firm ground of evidence of the divinity and truth of the Scriptures.

I have only one more point of harmony to notice. There is a coincidence truly wonderful between the revelations of the Bible of man's spiritual nature and immortality and his instinctive and inwardly-suggested sentiments. To ascertain how strong may be the convictions of human nature, uninstructed in divine revelation, on spirituality and immortality, read Xenophon's dying speech of Cyrus, or Cicero's beautiful treatise on old age. "Do not," said Cyrus to his children, "imagine, when death shall have separated me from you, that I shall cease to exist. I never could be persuaded that the soul ceased to live when death dissolved the vital union. I never could believe its intellectual powers were not enlarged and improved, when it escaped from connection with the body. The soul is invisible, both when it exists in the body and when it departs out of it. Therefore, my children, when death has removed me from your view, think of me as a celestial spirit." Cicero, when past eighty years old, says, "I feel a *conscious conviction* that this active, comprehensive principle, the human soul, cannot possibly be of a mortal nature. My mind, *by some secret impulse*, has ever been raising its views into future ages, strongly persuaded that I shall only begin to live when I cease to exist in this world." This *conscious conviction* is ever present to reflecting man. This *secret impulse* urges on every human soul. The idea of the spirituality and

immortality of the soul is not merely a belief. It is more than belief. It is an instinct—a sentiment. It is born in us. It grows with our growth, and strengthens with our strength. It lay at the foundation of all classic mythology. Under the strong convictions of this truth, Orpheus tuned his lyre to call back, from Proserpina's gloomy realm, his loved and lost Eurydice. Every man feels that death forms no part of the nature of his mind. He forms his idea of death chiefly from that of sleep, which is the emblem of death. The only difference between the sleep of a night and the sleep of the grave, seems to us one of time. The sleep of death is undisturbed, dreamless, and long; nor can we wake, though wife and children call us long and loud. So inborn, so interwoven with all our mental nature, is the notion of spirituality and immortality, that you cannot reason it out of a man, nor can he reason it out of himself. Should you bring your mathematical diagrams, and prove to him, with a rigidity that Euclid, nor Newton, nor Laplace ever obtained, that he has no spiritual nature, and no immortal soul, he would not believe you. He would be sure, from his own *conscious convictions*, from the *secret impulse of his own mind*, that there must be some fallacy in your reasoning, and an absurdity in your demonstration.

When, therefore, we take up the book of revelation, we see reflected from its pages the same truths which we have long and often been accustomed to see reflected from the quiet depths of our own minds. The truths of revelation seem to us perfectly-natural, old, and familiar truths. Our faith is founded, not so much on reasoning and logic, as on sentiment and consciousness. The word of God becomes to us spirit and life—a part of our own constitution and mental furniture. Really, it has always seemed to me, that the reflecting mind could not reject revelation if it would; and, surely, the candid and pure would not if it could.

453. *Universal adaptation of the doctrines and morals of Christianity to the human race.*—The system of doctrines and of morals of the Christian revelation, differs, in its elements of diffusion and perpetuity, from all other systems and codes. The doctrines and the laws of Moses and the prophets were greatly in advance of the age, and contain many moral precepts of universal adaptation and enduring obligation. But the greater part of the Mosaic law was ceremonial, and restricted in application to the Jewish people, and to the ante-christian age. Its purpose was specific and temporary, and when it had served that, it passed away.

The systems of intellectual and moral philosophy of the classic ages, were admirable for the times. But they were not of universal application, nor had they in their nature the elements of perpetuity.

Nothing is more difficult than to construct a system of law, or frame rules of action, for extended territories, or for enduring any considerable period of time. The Romans never succeeded in extending uniform laws and usages over the provinces of the empire; nor has the British government yet introduced the same code of laws in all its possessions. Even the government of the United States finds difficulty in administering uniform laws in all the states of this Union. To frame a system for perpetuity is more difficult than for extension. So mutable is human nature, so widely do circumstances vary with time, that no intelligence less than Divine can perfect a system equally fitted for extension and for duration.

Yet such a system; both of doctrine and morals, we have in the Bible. The historical records of the Bible have stood the test of all time with its wondrous advances in human knowledge. The doctrines of revelation have borne the scrutiny of keen metaphysical eyes, sharpened by all the improvements and changes in mental philosophy, from the

days of Aristotle to those of Kant. And the morals of the Bible, especially of the Christian Scriptures—what shall I say of them? Language fails me to express my conception of the wonderfully-original character, and the surpassingly-great intelligence, of the Christian Lawgiver. He surely was not of earth. All children of earth betray not only their maternal, but their local origin. Their character is the character of the age, and of the nation, in which they live. Their philosophy is the philosophy of the times and of the place. Their conceptions are founded on appearances present, both as to time and place. Moses was a Jew, and his theology, and philosophy, and morals were Jewish. The philosophy, the morals, and all the conceptions of Plato and Socrates were Grecian. The thoughts of Cicero were all cast in a Roman mold. Luther was, in all his views, thoroughly German; and even Wesley, who excelled any man of modern times, had, it must be confessed, some notions peculiarly and exclusively English. But the Founder and Lawgiver of the Christian dispensation was, in all his mental and moral character, entirely an *original*, such as the world had not only never seen, but of which it could not have ever conceived. And he presented to the world, and illustrated by his own life, a system of morals adapted equally to the individual and social condition of all men, in all countries, and in all times.

I venture to affirm, that the united efforts of all human moralists, if all who have ever lived could be brought together at one time and in one place, and could work harmoniously for a century, could not, without the aid of revelation, construct such a system of moral virtue as that of Christianity, so adapted to universal diffusion and acceptance, and to perpetual duration, amidst all the changes of this changing world.

454. *Conclusion.*—I have endeavored in these lectures

to call attention to some of the evidences, from nature and from science, of natural and revealed religion. On most points my notices have been brief and suggestive, rather than diffusive and exhaustive. Much more might be said. I have gathered my facts from every accessible source, and drawn therefrom such conclusions as seem to me natural, fair, and reasonable. I have not mentioned some assumed facts, which, in modern times, have been ostentatiously paraded before the public, nor attempted to refute the wild and fanciful theories which have been broached to account for nature without the intervention of a supreme and intelligent First Cause. The book called the *Vestiges of Creation*, may be named as a type of the new-fangled philosophies of the times. All I need say about works of this class, and all others that account for the existence and relations of things in a mode inconsistent with the correctly-interpreted teachings of the Bible, is, that their facts are not well-authenticated, and their theories are crude and ill-digested. He who should read such speculations as fact and truth, would be about as wise as he who should take the tales of *Arabian Nights* as veritable history.

I have never read nor heard of a well-authenticated fact of science, which, so far as it has had any bearing at all on revelation, has not verified and confirmed it. I have more confidence in the historical parts of the Bible, than I have in any human history, ancient or modern. I believe the history given in the Bible of the life of Jesus Christ, can be sustained by facts and arguments stronger than can be brought to sustain the truth of any history yet written of George Washington.

I have as much confidence in the truth of the doctrines of revelation, as I have in the clearly-demonstrated theorems of geometry. And as to the moral philosophy of the Christian dispensation, perfection itself can attain no higher

point. On the Bible, therefore, am I willing to rest all my interests of body and of soul, for time and for eternity. And this I say, after having thought my way step by step, and having, from the constitutional tendency of my own mind, subjected the doctrines of revelation to a rigid scrutiny, to which I would hardly subject a mathematical theory. I would, therefore, say to all, who may think my opinion of any account, fear not to bring revelation to the test of science. Be assured, if there seem an inconsistency between any chapter of any department of science and the teachings of revelation, there must be some error in the assumption of fact, or some mistake in interpretation, or some fallacy in your reasoning.

THE END.



